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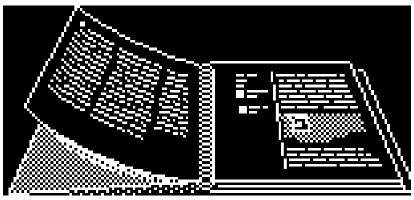

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The Split Margin Approach to Syllable Structure*

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1 Introduction

In this paper we focus on the similarities tying together the second segment of an onset cluster and a singleton coda segment. We offer a proposal based on Baertsch (2002) accounting for this similarity and show how it captures a number of observations which have defied previous explanation. In accounting for the similarity of patterning between the second member of an onset and a coda consonant, we propose to augment Prince & Smolensky's (P&S, 1993/2002) Margin Hierarchy so as to distinguish between structural positions that prefer low sonority and those that prefer high sonority. P&S's Margin Hierarchy, which gives preference to segments of low sonority, applies to singleton onsets; this is our M_1 hierarchy. Our proposed M_2 hierarchy applies both to the second member of an onset and to a singleton coda. The M_2 hierarchy differs from the M_1 hierarchy in giving preference to consonants of high sonority. Splitting the Margin Hierarchy into the M_1 and M_2 hierarchies allows us to explain typological, phonotactic, and acquisitional observations that have defied previous explanation. In Section 2 of this paper, we briefly provide background on the links that tie together the second member of an onset and a singleton coda. In Section 3, we review P&S's Margin Hierarchy, showing that it becomes problematic when extended to coda consonants. We then offer our proposal for a split margin hierarchy. Section 4 extends the split margin approach to complex onsets. We then show how it is able to account for various typological, phonotactic, and acquisitional observations. In Section 5, we will conclude the paper by briefly sketching how the split margin approach enables us to analyze syllable contact phenomena without requiring a specific syllable contact constraint (or additional hierarchy) or reference to an external sonority scale.

2 The links between the second member of an onset and a singleton coda

There are a number of phonological phenomena from typology, acquisition and phonotactics that point to a similarity in patterning between a coda consonant and the second member of an onset. One relatively well-known manifestation of this similarity comes from work on sonority such as that of Clements (1990) where it is observed that there is a preference for low sonority segments as a singleton onset and high sonority consonants as a singleton coda. In onset clusters, though, the preference is for a low sonority consonant followed by one of high sonority. This follows from the Sonority Sequencing Principle (Selkirk 1982, Blevins 1995, among others) which holds that sonority rises in moving from the beginning of the syllable toward the peak. As a result, clusters of an obstruent plus a glide or liquid are

* Earlier versions of this paper were presented at the Manchester Phonology Meeting in May 2003, at the Leiden sonorants workshop in September 2003 and at ZAS in October 2003. We thank the attendees of those talks for their comments, but especially Laura Downing, Tonio Green, T. A. Hall, Silke Hamann, Barbara Stiebels and Sabine Zerbian.

common among languages that allow onset clusters, while obstruent plus nasal or nasal plus liquid clusters are less common. Consequently, both the second member of an onset and a singleton coda prefer consonants of high sonority. (To be clear, in our discussion of onset clusters we do not consider the matter of sibilant-plus-stop clusters which we do not consider to be proper onset clusters. While these clusters can occur word-initially in many languages, they frequently display behavior that distinguishes them phonologically from other syllable-initial clusters and are often best analyzed with the sibilant being adjoined at a higher level of prosody, or, perhaps, in the case of /st/ clusters as single segments. See Bagemihl 1991, Davis 1990, and Selkirk 1982 for analyses regarding s-clusters in different languages, and Barlow 1997 for the developmental difference between s-clusters and other initial clusters in child phonology.)

A further manifestation of the similarity of patterning between the second member of an onset and a coda comes from the structure of syllable inventories, both in fully developed languages and in first language acquisition. Kaye and Lowenstamm (1981) observe that if a language permits onset clusters (i.e. CCV syllables) then it must have CVC syllables, but the reverse is not true; a language can have CVC syllables without permitting CCV syllables. That is, the presence of an onset cluster in a language implies the presence of a coda consonant. This characteristic is also reflected in the first language acquisition of structural slots within the syllable. As noted by Lleó and Prinz (1996) and Levelt, Schiller, and Levelt (1999), CV syllables commonly appear first in acquisition, followed by CVC syllables and finally onset clusters. This order is something that can be formally explained if there is a link between coda segments and second onset segments. The link between onset cluster and coda in acquisition can also involve the specific quality of the segment. An interesting case of this comes from Fikkert (1994). In this study, Jarmo, a child acquiring Dutch as his first language, has liquids as second members of onsets and as singleton codas at around the age of 24 months, but does not have liquids as single onset consonants at this age. From one perspective, such a pattern seems odd since one might assume that the presence of a liquid as a second member of an onset cluster would imply its presence as a singleton onset, but that implication does not hold in acquisition.

Finally, we find phenomena from phonotactics that suggest a link between the second member of an onset and a coda as well. There are some fairly well-known examples of constraints against words with identical consonants flanking the nuclear vowel only when the word begins with an onset cluster – not when the word begins with a single consonant. For example, as noted by researchers such as Clements and Keyser (1983), Davis (1988), and Fudge (1969), English lacks syllables like *[plɪl] but allows for ones like [lɪlt]. In other words, the constraint is against a syllable where the second onset segment and the first coda segment are identical.

In the next section we will focus on the high sonority preference for coda consonants and offer our split margin proposal whereby the coda is governed by the M_2 hierarchy which gives preference to high sonority consonants. In Section 4 we extend the split margin approach to complex onsets showing how it is able to explain the similarity of patterning between the second onset segment and a singleton coda.

3 Syllable Margins in Optimality Theory – The Split Margin Proposal

In order to put our split margin proposal in context, we will begin with a short overview of Prince and Smolensky's (1993/2002) analysis of onset segments. P&S give us the familiar constraints in (1a) along with their Margin Hierarchy in (1b). This accounts nicely for the behavior of onsets, encoding both the preference to have an onset in the first place (the ONSET constraint) and the preference for low sonority segments to fill onset position (the Margin Hierarchy). We will call P&S's Margin Hierarchy the M_1 hierarchy to distinguish it from our proposed M_2 hierarchy. Note here that we do not include glides as a separate category in the M_1 hierarchy. We treat glides and high vowels both as [+hi] vocalic segments.

(1) Syllable margins (onsets)

a. Onset encourages syllables with onsets

ONSET >> FAITH	onsets are required
FAITH >> ONSET	onsets are optional

b. Margin Hierarchy (M1) incorporates the preference for low sonority onsets.

$*M_1/[+lo] >> *M_1/[+hi] >> *M_1/[r] >> *M_1/[l] >> *M_1/Nas >> M_1/Obs$

The preference for low sonority onsets is reflected typologically by a number of languages in which high sonority segments are avoided in onsets. For example, in the Siberian (Turkic) language Yakut in (2), both [r] and [j] are systematically avoided in onset position (Baertsch 2003b, based on data from Schönig 1988, Krueger 1962, and Kharitonov 1982). They do not occur word-initially, do not occur as the second consonant in a two-consonant word-medial cluster (Yakut does not allow onset clusters), and they do not occur as geminates. Other consonants can fill these positions. The segments [r] and [j] do occur as codas and intervocalically. We analyze intervocalic instances of [r] and [j] as standing in coda position, which is consistent with how Yakut borrows Russian words that begin with these sounds as shown in (2). An initial [r], when encountered in a borrowing, takes a prothetic vowel and an initial [j] hardens to [dʲ] (2a). Medial VCrV and VCjV clusters are simplified (2c). Given this distribution, the two most sonorous consonants of Yakut are banned in onset position, reflecting a $*M_1/[+hi] >> *M_1/[r] >>$ FAITH constraint ranking.

(2) Distribution of Yakut [r] and [j]

a. Initial /r/, /j/ disallowed

Yakut	[äriäntä]	<	Russian	*rénta*	'rent'
	[dʲuolka]	<		*ëlka*	'fir, Xmas tree'

b. [r] and [j] allowed as codas

[ïar] 'heavy'
[ïj] 'moon, month'

c. Medial *VC.rV, *VC.jV clusters disallowed

Yakut	[kuudara]	<	Russian	*kúdri*	'curls'
	[bïlaattʃïja]	<		*plat'e*	'dress, gown'
	[sibiiɲɲä]	<		*svín'ja*	'pig'

The situation in Gujarati, an Indo-Aryan language of India, shown in (3) is similar (de Lacy 2001, based on data from Cardona 1965). Here, the labial glide is a dispreferred onset and has an obstruent allophone [v] that appears in onset position (3a). [w] is freely parsed in coda position and can occur as the second member of an onset cluster. Intervocalically, [w] and [v] are in free variation (3c). We would analyze the free variation as reflecting variation in the syllabification as well as variation in surface segments: [w] surfaces when the segment is parsed as a coda and [v] surfaces when the segment is parsed as an onset.

(3) Distribution of Gujarati [w] and [v]

a. [w] is neutralized to [v] initially: [vat] *[wat] 'matter, story'

b. [w] can appear in codas: [gaw] 'cow'

c. [w] is in free variation with [v] intervocalically: [səwar] ~ [səvar] 'morning'

One way the low sonority preference for onsets manifests itself in first language acquisition is in the order of acquisition of onset consonants. It is commonly the case that the first onsets a child acquires are stops with more sonorous segments being acquired in this position at later stages. Before the more sonorous segments are acquired, we often find high sonority underlying segments surfacing as lower sonority segments. We find exactly this pattern in Fikkert's (1994: 57-62) data on Jarmo's acquisition of Dutch in (4). Jarmo initially produced stop onsets, which were later followed by nasals, then liquids, then glides. When substitutions occurred (both before and after those segments first appeared target appropriately), the surface segment was less sonorous than the underlying segment. This acquisition pattern is straightforwardly accounted for by the gradual demotion of the M_1 constraints below the relevant faithfulness constraint.

(4) Acquisition of Dutch onsets

a. Stop onsets are present at 1;4

daar	/daːr/	[da]	'there'	1;4.18

b. Nasal onsets begin to appear after 1;9

meer	/meːr/	[miː]	'more'	2;0.28
muis	/mœys/	[pœys]	'mouse'	2;1.22
regen	/reːχə(n)/	[teːχə]	'rain'	1;11.20

c. Liquid onsets acquired after 2;1

leeuw	/leːw/	[leːw]	'lion'	2;1.22
wipwap	/ʋipʋɑp/	[piːpɑ]	'seesaw'	1;8.12
		[liːpaː]		2;1.8

d. Glides appear after 2;3

water	/ʋaːtər/	[ʋaːtə]	'water'	2;4.1

When we extend P&S's Margin Hierarchy to the analysis of codas, we run into difficulty given the preference for high sonority coda segments, which we assume to be independent of the issue of coda moraicity (for example, the presence of a coda in Yakut does not interact with stress placement or vowel length). P&S's Margin Hierarchy encodes preference for low sonority consonants, not high sonority ones. This difficulty is mentioned by P&S (§8.3.2) who conclude that the treatment of the coda is yet to be fully explored in OT. Let us detail the problem and offer a proposal. NOCODA is the only constraint available in P&S that is analogous to ONSET. NOCODA is similar to ONSET in that it makes a categorical determination about codas as a unit (shown in 5a). The ranking of NOCODA with respect to FAITH determines whether codas are allowed or banned.

(5) Syllable margins (codas)

a. NoCoda discourages or bans codas

NOCODA >> FAITH	codas are banned
FAITH >> NOCODA	codas are optional

b. NoCoda explodes into the M2 hierarchy
$*M_2$/Obs >> $*M_2$/Nas >> $*M_2$/[l] >> $*M_2$/[r] >> $*M_2$/[+hi] >> $*M_2$/[+lo]

NoCoda is also similar to the M_1 hierarchy in that it is negatively phrased, militating against codas just as the M_1 hierarchy militates against particular segments filling onset position. The major drawback to NoCoda is that it cannot account for the segmental content of codas. Coupling NoCoda with Prince & Smolensky's Margin Hierarchy would result in a preference for low sonority rather than high sonority codas when codas are allowed. We propose that the NoCoda constraint is the encapsulation of a second margin hierarchy, the M_2 hierarchy in (5b), which does incorporate the high sonority preference. The ranking of this hierarchy is the reverse of the M_1 hierarchy, making obstruents the most marked segments in coda position and high sonority segments the least marked codas (Baertsch 2002).

Exploding NoCoda in this way gives us the tools we need to analyze the segmental content of coda segments while the absence of a coda counterpart to the Onset constraint (a constraint that would encourage syllables with codas as Onset encourages syllables with onsets) still ensures that codas are dispreferred in general.

We want to be clear that our proposed M_2 hierarchy in (5b) does not give preference for vowels in the coda, even though the M_2 constraint governing low vowels is the lowest ranked constraint in the hierarchy. The M_2 hierarchy interacts with the Peak hierarchy, and the comparatively low ranking nature of the *P/Vowel constraints causes a vowel to be pulled into the nucleus rather than being parsed as a coda. However, we do find in some languages, like English and Dutch, that long vowels and diphthongs seem to spill over into the M_2 position rather than being encased completely in the nucleus (cf. Baertsch 2002 for more detailed discussion of this point).

If we reconsider the Yakut case in (2), the ranking $*M_1$[+hi] >> $*M_1$/[r] >> Faith prevents [r] and [j] from surfacing in onset position. If that were the end of it, we would never see [r] as a surface margin segment in this language (unless, of course, [r] could fill the peak, which it cannot in Yakut). Any instance of underlying /r/ would force some violation of Faith in the winning candidate. Incorporating the M_2 hierarchy into the analysis offers another option: parsing an underlying /r/ as a coda. In this way, we can account for the insertion of the prothetic vowel in [r]-initial borrowings (2a) as providing a nucleus to which a coda [r] may attach with the constraint ranking $*M_1$[r] >> Dep >> $*M_2$/[r].

A second example of the interaction of segmental content with coda position comes from Randall Gess's (1998) analysis of coda loss in Old French. We have included some of his data in (6). Essentially, codas with sonority equal to or greater than alveolar fricatives were deleted with compensatory lengthening of the preceding vowel.

(6) Coda loss in Old French

	ca. 1050	**ca. 1200**	**gloss**
barde	[bardc]	[baːdə]	‘pack’
albe	[ałbə]	[awbə]	‘dawn’
ante	[ãntə]	[ãːtə]	‘aunt’
blasmer	[blazmer]	[blaːmer]	‘to blame’

Gess considers and rejects a NoCoda analysis of these data precisely because NoCoda cannot deal with the sonority facts of the change, including the fact that the change stopped short of [r] in some dialects. If NoCoda explodes into the M_2 hierarchy, this is no longer a problem. The loss of codas over time represents a change in the relative position of FAITH with respect to the M_2 hierarchy. In the early constraint ranking, FAITH is ranked between the M_2 constraint militating against very low sonority consonants (represented as $*M_2/T$ in the constraint ranking) and the M_2 constraint militating against alveolar fricatives ($*M_2/S$ in the constraint ranking). At the later stage, FAITH is between $*M_2$/[r] and $*M_2$/[+hi] as in (7).

(7) Old French constraint ranking

*M2/T >> Faith >> *M2/S >> *M2/Nas >> *M2/[l] >> *M2/[r] >> *M2/[+hi]

In the dialects in which coda [r] was not included in the change, FAITH dominates $*M_2$/[r]. In the other dialects, $*M_2$/[r] dominates FAITH. The compensatory lengthening is a result of the underlying segments being realized as vocalic, thus violating the M_2 constraints still dominated by FAITH.

It is also not uncommon to find languages in which low sonority segments, for example obstruents, are banned from coda position while high sonority segments are acceptable codas. Examples include Ponapean (Goodman 1995) and Sranan (Alber & Plag 2001, based largely on data from Smith 1987). Consider the Sranan data in (8).

(8) Sranan codas

ku.ne.ti	'goodnight'	*tran.ga*	'strong'	*shar.ki*	'shark'
sa.fri	'softly'	*mem.re*	'remember'	*mar.ki*	'mark'

Here, obstruents but not sonorants are banned from coda position. Nasals are apparently the most common coda segments, but several examples of coda [r] are given as well. Since English is the lexifier language for this Creole, it is faced with many illicit obstruent codas that must be eliminated. Medially, coda obstruents in Sranan are often deleted and word-finally, they are made syllabifiable by the addition of a nuclear vowel, as in the 'goodnight' example in (8). On our approach, the $*M_2$/Obs constraint in Sranan dominates FAITH and the remainder of the M_2 hierarchy is dominated by FAITH ($*M_2$/Obs >> FAITH >> $*M_2$/Nas …).

It is also worth noting that in acquisition, early codas are often high sonority segments, although the picture in acquisition is somewhat muddied by the problem of word-final consonants and their status as codas or as extrasyllabic segments (cf. Piggott 1999). For example, Fikkert's (1994: 171-172) account of the Dutch child Jarmo finds that the first word internal codas produced by this child are sonorants as in (9). He seems to avoid attempts at medial obstruent codas.

(9) Word medial consonant clusters in acquisition (Jarmo)

drinken	/ˈdrɪŋkə[n]/	[ˈtɪŋkə]	'to drink'	2;2.6
Selma	/ˈsɛlmaː/	[ˈʃɛlmaː]	name	2;3.9

Similarly, consider the data in (10) from Martohardjono (1989) which documents Jenny's acquisition of English.

(10) Medial clusters in English (Jenny at age 3;2)

a. Obstruent clusters are simplified: /VO.OV/ becomes [V.OV]
toothpaste [tu.peⁱt] *footprints* [fʊ.pɪns]

b. Nasal-Obstruent clusters surface: /VN.OV/ surfaces as [VN.OV]
blanket [bæn.tət] *rainbow* [reⁱm.bo]

Here, we see that Jenny deletes word-internal obstruent codas in (10a) but retains word internal nasal codas in (10b). Word final obstruents do surface in this case and we would analyze these segments as M_1 (onset) segments following Piggott (1999). The analysis of these developing systems would be similar to Sranan in (8) where the *M_2/Obs constraint dominates FAITH and the remainder of the M_2 hierarchy is dominated by FAITH.

4 The extension of the M_2 hierarchy to complex onsets and the links to the coda

Like single coda consonants, there is a preference for high sonority segments to fill the second member of an onset cluster. And like single coda segments, P&S's single Margin Hierarchy does not straightforwardly account for the sonority contour of onset clusters. Within OT, onset clusters have most commonly been examined in the past through constraints encoding a sonority distance requirement along with a language-specific sonority scale or by more specific (and more ad-hoc) constraints whose purpose is simply to ban a particular cluster outright. Here we propose that the M_2 hierarchy in (5b), shown to govern coda positions, also governs the second member of an onset. We repeat the M_2 hierarchy in (11b). Like NOCODA and the margin constraints, *COMPLEX is negatively phrased, militating against complex onsets wherever it happens to fall in the hierarchy (11a). What is missing from *COMPLEX is a mechanism that can judge the segmental content of a cluster as the margin constraints can.

(11) Syllable margins (complex onsets)

a. *Complex discourages or bans complex onsets

*COMPLEX >> FAITH	complex onsets are banned
FAITH >> *COMPLEX	complex onsets are optional

b. *M2/Obs >> *M2/Nas >> *M2/[l] >> *M2/[r] >> *M2/[+hi] >> *M2/[+lo]

We propose here that the M_2 hierarchy, in combination with the M_1 hierarchy can do just that (and can replace *COMPLEX). The M_1 hierarchy governs the first segment on an onset cluster and the M_2 hierarchy governs the second member. By having the M_2 hierarchy apply to both the second member of an onset and to the coda, we immediately account for the high sonority preference of both of these positions. Moreover, the other links mentioned in Section 2 between the second member of an onset and a coda, namely the phonotactic, acquisitional, and typological links that tie these positions together can be explained under our split margin approach. In this section we first consider some of the simpler analyses of the split margin approach to explain phonotactic links and some links in acquisition between these two positions. We then turn to the analysis of onset clusters through the conjunction of the margin hierarchies in order to offer insight to the typological link discussed in Section 2 whereby the presence of a complex onset in a language presupposes the presence of a coda in that language.

In Section 2 we mentioned the fairly well-known examples of phonotactic constraints against words with identical consonants flanking the nuclear vowel only when the word begins with an onset cluster – not when the word begins with a single consonant. These have been noted for English by researchers such as Clements and Keyser (1983), Davis (1988), and Fudge (1969) and for Dutch by Booij (1995: 42-47) and we show some examples for both languages in (12).

(12) Cooccurrence phenomena

a. English: OCP holds over M2

Identical M_2 within the syllable: *[$p_1l_2ɪl_2$], *[$p_1l_2ɪl_2p_1$]

Identical M_1 within the syllable: *Lyle* [$l_1aj_2l_1$], *klunk* [$k_1l_2ʌŋ_2k_1$]

Identical M_1 and M_2 within a syllable: *loll* [l_1al_2], *lilt* [$l_1ɪl_2t_1$], *clock* [$k_1l_2ak_2$]

b. Dutch: OCP holds over both M2 and M1

*/$C_1l_2Vl_2$/: *plol, *klol, *blol, *slol

/$l_1VV_2l_1$/ is 'strange': *lool, *leel, *laal, *luul, *loel, *liel

/l_1Vl_2/ is ok: lol /lɔl/ 'fun', lel /lɛl/ 'lobe', lal /lɑl/ 'to jabber', lul /lʏl/ 'penis'

For example, English disallows syllables like *[plɪl] but allows syllables like [lɪlt]. The difference between these two syllables from our perspective is that both instances of [l] in *[plɪl] are in M_2 position while in [lɪlt], the first [l] is in M_1 position and the second is in M_2 position. In showing the English and Dutch data in (12) we have indicated by the use of subscript numerals whether each margin segment constitutes an M_1 or M_2 position. What clearly emerges from this is that the phonotactic constraint can be viewed as an OCP type constraint holding over identical M_2 segments within a syllable. (We analyze coda clusters as essentially the reverse of onset clusters – an M_2 segment followed by an M_1 segment.)

The constraint in Dutch is similar to English in that identical M_2 segments within a syllable do not occur. Dutch may have a similar constraint against identical M_1 segments within a syllable as shown in (12b), although these data are complicated by the data with /r/. Forms including identical M_1 rhotics do occur (*raar* /raar/ 'strange', *roer* /ruur/ 'rudder') suggesting to us that the strangeness of /$l_1VV_2l_1$/ in Dutch may be due to something other than a constraint against identical M_1 segments, in which case Dutch will be just like English in banning only identical M_2 segments within the syllable. While there are further issues of detail in the cross-vowel phonotactics of both English and Dutch that we do not explore here, the split margin hierarchy is able to offer an explanation for why such phonotactic constraints occur at all.

Another situation where our split margin hierarchy can account for a phenomenon that has defied previous explanation comes from first language acquisition where it has sometimes been remarked that children may acquire segments in complex onsets before acquiring them as single onsets. A striking case of this comes from the acquisition of Dutch by Jarmo reported by Fikkert (1994), though the discussion here is based on that of Baertsch (2002) which proposes a rhyme structure for these data that differs from Fikkert's. Jarmo begins to produce onset clusters consisting of an obstruent followed by a liquid several months before producing singleton liquid onsets. From one perspective, this pattern seems odd. If rhotics and laterals can occur as the second member of an onset, shouldn't they also appear as a singleton onset? Our response to this question is no. Given our analysis, there is no expectation that a segment must be allowed as a singleton onset (an M_1 position) before occurring as the second segment in an onset cluster (an M_2 position). We would, however, expect to see a connection between when segments begin to appear as singleton codas and in second onset position because both are M_2 position. And Jarmo's pattern of acquisition supports our expectation. He acquires onset clusters at roughly the same time he acquires sonorant codas. On our analysis, Jarmo had demoted the *M_1/Nasal and *M_1/Obstruent constraints below FAITH at this point in time, allowing obstruents and nasals to surface as onsets and had also demoted *M_2/Nasal and *M_2/Liquid below FAITH allowing sonorants to surface in the available M_2 positions.

Thus, the split margin hierarchy can account for developing phonology like that witnessed in Jarmo where there is a close link between the second member of an onset and the coda. The presence of a consonant as a second member of an onset need not imply its presence as a singleton onset.

There are two questions that emerge from our discussion and analysis of Jarmo's system, First, can there be a fully developed phonology like Jarmo's in which some segments can appear in M_2 but not in M_1 position? We argued in Section 3 that Yakut is one such language, where [r] and [j] surface only in M_2 (coda) position (cf. (2) above). And Gujarati, in (3) above allows [w] in both M_2 positions (coda and second onset position) but not in M_1 position. Possible additional languages to consider would be those Australian languages such as Arrernte (Breen and Pensalfini 1999) which are claimed to lack onsets. Second, do we claim that it should always be the case in acquisition that in languages with onset clusters, the acquisition pattern would always be the one displayed by Jarmo where there is a stage in which the child has a sonorant as a second member of an onset without having it as a singleton onset? Here the answer is clearly no. As a specific example, consider the discussion of the acquisition of Greek by the child Sofia discussed in Kappa (2002, 2003). Between the age of 1 year 10 months and 2 years 10 months Sofia acquired all the single onset consonants of Greek with no sonority restrictions. During the same period Sofia did not produce onset clusters. She also did not have any (word-internal) coda consonants. From our perspective, this system can be analyzed with the entire M_1 hierarchy ranked below FAITH and the entire M_2 hierarchy ranked above FAITH.

This ranking prevents the realization of any M_2 consonant but allows for the realization of any consonant in M_1 position. Thus, on this ranking of the two margin hierarchies with respect to the faithfulness constraints, all consonants are allowed as singleton onsets before any of them appear as second member of an onset, thus contrasting with Jarmo's system.

We now turn to the link from syllable typology that connects the coda with the second member of an onset. As mentioned in Section 2, Kaye and Lowenstamm (1981) observe that if a language permits onset clusters (i.e. CCV syllables) then it must have CVC syllables, but the reverse is not true; a language can have CVC syllables without permitting CCV syllables. That is, the presence of an onset cluster in a language implies the presence of a coda consonant. While we are aware of possible counterexamples to this implication, they seem to be rare and often subject to a reanalysis of the apparent onset cluster. (For example, Kaye 1985 argues that the liquid in a CLV sequence in Vata patterns as an element of a rising diphthong while Steriade 1994 argues for a single segment approach to apparent complex onsets in Mazateco.) As far as we are aware, this implication has defied explanation. We show here that the implication follows logically given our split margin approach to the syllable. To see this, we must first digress to detail how the specific nature of onset clusters is accounted for under the split margin approach.

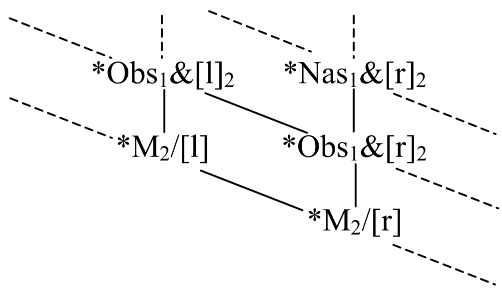
In the split margin approach to the syllable (as developed in Baertsch 2002), the nature of onset clusters is accounted for by conjunction of the M_1 and the M_2 hierarchies. Through exhaustive conjunction of these two hierarchies, we generate a set of constraints that addresses the sonority relationship between the two segments of every possible onset cluster. We list a small part of the conjoined hierarchy in (13).

(13) The conjoined margin hierarchy

… >> *Obs1&Nas2 >> *Obs1&[l]2 >> *Obs1&[r]2 >> *Obs1&[+hi]2 …

In these constraints, the M_1 component has been listed first and abbreviated simply to $*Obs_1$ for $*M_1/Obs$, and so on. The M_2 component is listed second using the same abbreviation format. So the first constraint in (13), $*Obs_1\&Nas_2$, is violated by an output onset cluster consisting of an initial obstruent followed by a nasal and so on. There are two important points to note about these constraints. Firstly, the domain for these conjunctions is adjacent M_1 and M_2 segments within a syllable and the order of the two segments is not specified. Therefore, the same constraint, say $*Obs_1\&[l]_2$ would potentially govern an onset cluster consisting of an obstruent plus [l] or a coda cluster consisting of an [l] followed by an obstruent since coda clusters will be the mirror image of onset clusters. To be clear, however, we do not predict that occurring coda clusters in a language should always be only the mirror image of occurring onset clusters. Additional constraints such as OCP constraints also affect these clusters. Our discussion here necessarily focuses only on onset clusters. Secondly, conjunction inherits some of the ranking relationships of the component constraints. This is shown in (14) for a subset of the conjoined constraints and follows Downing (1998), Itô & Mester (1998), Smolensky (1993), Spaelti (1997) and others.

(14) Ranking of conjunctions



A conjoined constraint dominates both of its component constraints, so the conjoined constraint $*Obs_1\&[l]_2$ would have to dominate both $*M_1/Obs$ and $*M_2/[l]$. In addition, two conjoined constraints that share one component constraint, like $*Obs_1\&[l]_2$ and $*Obs_1\&[r]_2$, inherit the ranking of the component that differs, in this case $*M_2/[l]$ outranks $*M_2/[r]$ so $*Obs_1\&[l]_2$ outranks $*Obs_1\&[r]_2$. What these two ranking arguments do for the conjunction of the two hierarchies is to automatically impose upon the set of conjoined constraints a ranking that would predict exactly what we find typologically. The least marked clusters (based on the lowest ranking constraints) are clusters consisting of an obstruent plus a liquid or glide – the types of clusters that are common cross-linguistically. More marked clusters like obstruent plus nasal or nasal plus [r] clusters are governed by conjunctions that dominate the obstruent plus liquid conjunctions. Equal sonority clusters are governed by even higher ranking constraints and falling sonority (onset) clusters even higher. In other words, conjunction of the two hierarchies gives us the markedness facts and the sonority sequencing principle without having to impose a constraint ranking on it – the ranking is inherited along with the component constraints. (A side issue that arises is the matter of vocalic segments in the conjoined hierarchies. If we are conjoining the whole of the M_2 hierarchy to the complete M_1 hierarchy and the lowest ranking constraint on the M_2 hierarchy is $*M_2/[-hi]$, shouldn't that make clusters of obstruent plus non-high vowel the best clusters? As we mentioned earlier, the M_2 hierarchy interacts with the Peak hierarchy. Vocalic segments that could potentially be M_2 segments within an onset cluster are pulled into the nucleus instead by the Peak constraints. The issue of the potential ambiguous behavior of high vowels as peaks or margins is beyond the scope of the present paper.)

We give a more concrete example from Spanish to illustrate how the conjunction of the two margin hierarchies gives us the preferred onset clusters as an obstruent plus liquid (or glide) without having to impose sonority sequencing or sonority distance constraints. In Spanish, as shown by the data in (15a), obstruent plus liquid sequences are allowed as onsets but potential obstruent plus obstruent onset sequences are not allowed and can be eliminated by prothesis as shown in (15b).

(15) Exemplification from Spanish (only obstruent + sonorant onsets are allowed)

a. /blanko/ [blaŋ.ko] 'white'

b. /sposa/ [es.po.sa] 'wife'

The different outcomes of the two (potential) initial onset clusters in (15) can be accounted for with the ranking in (16) where the relevant Faithfulness constraint (DEP) is ranked between the high ranking conjoined constraint that rules out two obstruents and the lower ranked one that militates against an obstruent-liquid cluster.

(16) Constraint ranking for Spanish:

*Obs1&Obs2 >> Dep >> *Obs1&*[l]2, *M2/Obs >> *M2/[l], *M1/Obs

As explained above, the conjoined constraint $*Obs_1\&Obs_2$ must be intrinsically ranked higher than the conjoined constraint $*Obs_1\&*[l]_2$ because of their difference in the M_2 conjuncts – $*M_2/Obs$ outranks $*M_2/[l]$. We give tableaux in (17) and (18) for the data in (15) to make clear our analysis.

(17) Complex onset (Spanish)

/blaŋko/ [blaŋ.ko] 'white'

/bla/	$*Obs_1\&Obs_2$	DEP	$*Obs_1\&[l]_2$	$*M_2/Obs$	$*M_2/[l]$	$*M_1/Obs$
bla			*		*	*
eb.la		*!		*		

Prothetic vowel (Spanish)

/sposa/ [es.po.sa] 'wife'

/spo/	$*Obs_1\&Obs_2$	DEP	$*Obs_1\&[l]_2$	$*M_2/Obs$	$*M_2/[l]$	$*M_1/Obs$
spo	*!					*
es.po		*		*		*

We thus see that the conjunction of the two margin hierarchies can account for the preferred onset cluster of an obstruent plus sonorant without the need for imposing sonority sequencing or sonority distance constraints or even imposing an external sonority hierarchy. Crucially, it is the use of the M_2 hierarchy for determining acceptability of coda segments combined with the use of the same M_2 hierarchy through constraint conjunction to account for the acceptability of onset clusters that links the two syllable positions together. What follows as a natural consequence of this is the implication noted by Kaye and Lowenstamm (1981) that the presence of onset clusters in a language implies the presence of codas. This is because if a conjoined $*M_1\&*M_2$ constraint is ranked below FAITH so as to permit the $M_1\&M_2$ onset cluster, then, necessarily, by the logic of constraint conjunction, the corresponding $*M_2$ conjunct must be even lower ranked which allows for that single M_2 segment in a coda. Thus, considering the Spanish example in (17), the faithfulness constraint DEP outranks

$*Obs_1\&*[l]_2$ permitting the complex obstruent plus [l] onset, and $*Obs_1\&*[l]_2$ outranks $*M_2/[l]$, allowing the singleton coda [l]. Notice that our split margin approach also accounts for the fact that there are many languages that have codas which lack complex onsets. In such a language the M_2 hierarchy would be ranked below FAITH allowing for codas, but the conjoined M_1 and M_2 hierarchies would be ranked above FAITH. This is shown in (19) and is the situation in Yakut, discussed above.

(19) The constraint ranking for a language with codas but lacking complex onsets

*M1&M2 >> Faith >> *M2

We view this as a strong point of the split margin approach. It formally accounts for Kaye and Lowenstamm's implication that the presence of an onset cluster in a language implies the presence of codas and we note that the approach developed here can be formally extended to account for the observation noted by Lleó and Prinz (1996) and Levelt, Schiller, and Levelt (1999) that CV syllables appear first in acquisition, followed by CVC syllables and finally onset clusters.

5 Conclusion

In this paper we have focused on the similarities tying together the second segment of an onset cluster and a singleton coda segment. We have offered a proposal based on Baertsch (2002) that splits the Margin Hierarchy of Prince & Smolensky (1993/2002) so as to distinguish between structural positions that prefer low sonority and those that prefer high sonority. Our proposed M_1 hierarchy gives preference to segments of low sonority and applies to singleton onsets; our proposed M_2 hierarchy applies both to the second member of an onset and to a singleton coda and gives preference to consonants of high sonority. As we have shown in this paper, splitting the Margin Hierarchy into the M_1 & M_2 hierarchies allows us to explain various typological, phonotactic, and acquisitional observations that have defied previous explanation.

There are a variety of implications that emerge from our approach that we do not pursue here. This includes the possible analysis of a word final consonant as either an M_1 or M_2 segment, thus accounting for Piggott's (1999) delineation that final consonants in some languages are coda-like (an M_2 segment on our analysis) and in other languages onset-like (an M_1 segment on our analysis). It also includes the possible analyses of on-glides in different languages (and within the same language) as either onset segments or peak segments given the tension between the low-ranking Peak and M_2 constraints both of which favor high vowels (see, for example, Davis and Hammond 1995 and Baertsch 2003a for English.) Finally, as developed in Baertsch (2002), the split margin approach can account for syllable contact effects (i.e. the preference to avoid rising sonority over a syllable boundary) without the need for additional syllable contact constraints. Syllable contact effects are handled much like complex onsets but within a larger domain. Consider one example of this, namely Bat-El's (1996) discussion of Modern Hebrew blends. Bat-El shows that the sonority profile is a crucial factor in determining the linear order of component monosyllabic elements in blends. For example, the blend of the Hebrew words [xay] 'alive' and [bar] 'wild' could hypothetically be either *[barxay] or [xaybar] 'wildlife safari', only the latter of which is correct. While Bat-El proposes both a syllable contact constraint and a syllable contact slope constraint our split margin approach readily accounts for this given that a coda is in M_2 position and prefers a higher sonority consonant and a single onset is in M_1 position preferring a consonant of low sonority. Consider the tableau in (20).

(20) Hebrew blends

xáy 'alive, he lives' *plus bár* 'wild' = *xaybár* **barxay*

	*Obs$_1$&[r]$_2$	*Obs$_1$&[+hi]$_2$	*M$_2$/[r]	*M$_2$/[+hi]	*M$_1$/Obs
xaybár		*	*	*	**
barxay	*!		*	*	**

Conjunction of the M_1 and M_2 hierarchies over the domain of the word, in addition to the syllable domain relevant for complex margins discussed earlier, will select the candidate with the larger sonority fall as shown in (20). Thus, our split margin proposal can account for syllable contact effects without reference to specific syllable contact constraints or other sonority distance constraints.

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Mechanisms of Contrasting Korean Velar Stops: A Catalogue of Acoustic and Articulatory Parameters

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Abstract

The Korean stop system exhibits a three-way distinction in velar stops among /g/, /k'/ and /k^h/. If the differentiation is regarded as being based on voicing, such a system is rather unusual because even a two-way distinction between a voiced and a voicless unaspirated velar stop gets easily lost in the languages of the world especially in the case of velar stops. One possibility for maintainig this distinction is that supralaryngeal characteristics like articulators' velocity, duration of surrounding vowels or stop closure duration are involved. The aim of the present study is to set up a catalogue of parameters which are involved in the distinction of Korean velar stops in intervocalic position.

Two Korean speakers have been recorded via Electromagnetic Articulography. The word material consisted of VCV-sequences where V is one of the three vowels /a/, /i/ or /u/ and C one of the Korean velars /g/, /k'/ or /k^h/. Articulatory and acoustic signals have been analysed. It turned out that the distinction is only partly built on laryngeal parameters and that supralaryngeal characteristics differ for the three stops. Another result is that the voicing contrast is not a matter of one parameter, but there is always a set of parameters involved. Furthermore, speakers seem to have a certain freedom in the choice of these parameters.

1 Introduction

The voicing contrast in stops is often seen as the result of laryngeal activities, vocal fold vibration for voiced stops, lack of vocal fold vibration or aspiration for voiceless stops. Vibration of the vocal folds, however, demands a difference between sub- and supralaryngeal pressure (Fry 1982: 62f). The supralaryngeal pressure has to be lower than the pressure below the glottis. For stops this precondition of pressure difference is especially difficult to fulfil, since the mouth cavity is constricted at some point so that the air stream is blocked and the pressure behind the constriction increases with more and more air coming from the glottis. Velar stops are particularly affected, because the constriction is situated rather back so that the cavity behind the constriction becomes small and the pressure in this cavity increases quickly (Ohala 1983).

Looking at the languages of the world this results in an asymmetric typology for stops. Regarding the three most common places of articulation, bilabial, alveodental and velar, so called "voiced" and "voiceless" stops are not distributed evenly. Many languages have a "missing /g/" (Maddieson 1984: 2.6, 2003) which can be explained by the difficulties in producing a voiced velar. If, however, voicing gets lost, /g/ and /k/ can no longer be distinguished and merge.

Korean, however, contradicts this general pattern in exhibiting not only a two-way but a three-way contrast for velar stops. At least in intervocalic position, this contrast is often described as being primarily based on voicing. The Handbook of the IPA, for example, describes /g/ as voiced in intervocalic position, /k'/ as a voiceless unaspirated fortis stop syllable-initially, without saying anything about intervocalic position, and /k^h/ as a strongly aspirated voiceless sound in the same position (Lee 1999: 112). Han and Weitzman (1970) distinguish aspirated, weak and strong stops and state that the weak stops are voiced between voiced sounds. Similarly, Umeda & Umeda (1965) describe the “forced“ and “aspirated“ stops as voiceless and the “unaspirated” as voiced between two voiced sounds. Kim (1996) uses a different terminology and also different symbols. She calls the stops lenis, fortis and aspirated (/k/, /k'/, /k^h/), which stresses her view that consonant voicing is not contrastive in Korean and that voiced stops are allophones of lenis stops in intervocalic position.

If it is already difficult to distinguish two velar stops merely by voicing, the question is how the three-way contrast in Korean is realized. One strategy could be to make use of supralaryngeal mechanisms. They could be aimed at intensifying the contrast produced by voicing in prolonging the voicing during closure. A number of supralaryngeal strategies to sustain voicing during closure have been proposed, for example by Houde (1968) and Ohala (1983), who suggested that forward movement performed by the tongue during velar stop closure aims at enlarging the cavity and thereby reducing the pressure behind the constriction so that voicing can be sustained for a longer period. For velar stops, however, those mechanisms seem to be especially difficult to perform, since the cavity behind the closure is particularly small. Other studies, however, contradict this view in saying that those loops are not performed in order to sustain voicing. Mooshammer et al. (1995), for example found for German that the loops are larger for /k/ than for /g/. Kent & Moll (1972) propose airstream mechanisms as a reason for looping patterns, Perrier et al. (2003) suggest biomechanical reasons. Löfqvist & Gracco (2002) propose cost minimization principles as a reason for looping patterns in that they regard the whole movement as being planned from the beginning of the first vowel to the end of the second vowel.

If supralaryngeal strategies do not sustain voicing they could nevertheless have a function in contrasting the stops. Parameters like vowel duration have been proved to influence the stop contrast (Luce & Charles-Luce 1985). Other parameters such as stop closure duration or ratio of closure have also been proposed.

There are a number of acoustic studies of Korean velars (e.g. Cho et al. 2002, Choi 2002, Han & Weitzman 1970, Kagaya 1971, 1974), and also a few on articulation, (Sawashima & Park 1979 for final stops, Silverman & Jun 1994 for consonant clusters, Hirose et al. 1974 for word initial stops). However, to our knowledge, there are no studies on the articulation of intervocalic stops.

The present study examines supralaryngeal as well as laryngeal parameters of the Korean velar stops and sets up a list of parameters that are involved in the distinction among velar stops. The characteristics of each stop will be described and possibilities of interspeaker variability will be referred to. Although vowel context has a strong influence on the distinction of the three stops, the contrast has been analysed independently of vowel context only so far.

2 Methods

2.1 Procedure

Two Korean speakers, one male (SH) and one female (HS) were recorded via Electromagnetic Articulography (Carstens AG 100). This system is based on measuring induced current in a magnetic field, which is generated by three transmitter coils. The transmitter coils are attached midsagittally to a helmet on the subject's head (cf. fig. 1). There is one transmitter coil behind the neck, one near the chin and a third one near the forehead. Within the magnetic field a position dependent current is induced in five sensors ("receiver coils"). Two of them, one at the bridge of the nose, the other one at the upper incisors, serve as reference to enable compensation for head movements. The other three sensors are attached to the tongue, one at the tongue tip (tt), one at the tongue dorsum (td) and the third one at the tongue back (tb). The sensors were located at equal distance from about 1cm to about 5cm from the tongue tip. Depending on the position of the sensors in the magnetic field the amplitude of the induced current changes and the movements of the tongue points can be tracked. The sampling frequency was 500 Hz. For the purposes of this study only the data from the tongue back have been analysed.

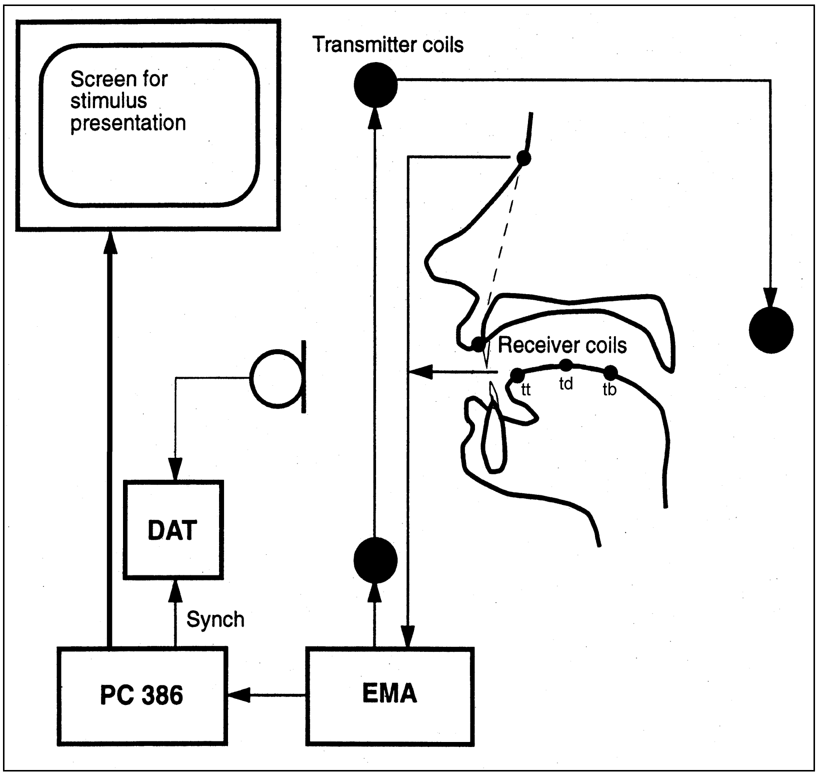

Figure 1: Electromagnetic Articulography

The word material consisted of 26 Korean words and one nonsense word. There was one word for each possible VCV-sequence where V is either /a/, /o/ or /u/ and C one of the three velar stops. The nonsense word was chosen because there is no word for the sequence /uk^{h}u/ in Korean. There were two randomised sessions, each of the 27 words was repeated five times in succession in each session. For technical reasons, there was a time limit for the experiment. That is why carrier sentences could not be used.

Table 1: word material

word	VCV-sequence	English translation
pagaci	/aga/	gourd
kak'ai	/ak'a/	near
ak^hasia	/a k^h a/	acacia
sagilo	/agi/	made of chinaware
ak'ita	/ak'i/	to save money
sak^hita	/ak^hi/	to grow
paguni	/agu/	basket
pak'uta	/ak'u/	to change
sak^hula	/ak^hu/	cherry flower
kigahata	/iga/	to raise one's family
cik'aci	/ik'a/	you too
mik^hael	/ik^ha/	-name-
pigita	/igi/	to be equal
pik'ita	/ik'i/	to illuminate obliquely
pik^hita	/ik^hi/	to line up
piguni	/igu/	buddhist nun
mik'ulaci	/ik'u/	the loach
mik^hulaci	/ik^hu/	the loach
pugahata	/uga/	to add
acuk'ali	/uk'a/	ricinus
uk^hano	/uk^ha/	how to do?
ukida	/ugi/	to insist
uk'ita	/uk'i/	it is funny
$chuk^h$ita	/uk^hi/	to compliment
suguhata	/ugu/	to be conservative
puk'umi	/uk'u/	wheat pancake
suk^huli	/uk^hu/	-nonsense word-

2.2 Analysis

2.2.1 Acoustic segmentation and labelling

Acoustic labelling marks specific events in the signal and thus divides it into segments. In this case the following segments were of interest: the first vowel (V1), the second vowel (V2), the closure, and voicing into closure, which is the voicing that still takes place after closure onset. Consequently, six events were labelled (cf. figure 2):

- the beginning of V1: onset of the second formant[1],
- the end of V1 and beginning of closure: offset of the second formant,
- voice offset: the end of vibration of the glottis, in the oscillogram this is the end of clear periodic movement,
- the end of closure and beginning of aspiration: the burst,
- the end of aspiration and beginning of V2: onset of the second formant,
- the end of V2: offset of the second formant.

[1] F2 onset was defined not as the point in time where the second formant becomes visible but where its intensity becomes characteristic for a vowel. F2 offset is the point where intensity gets lost.

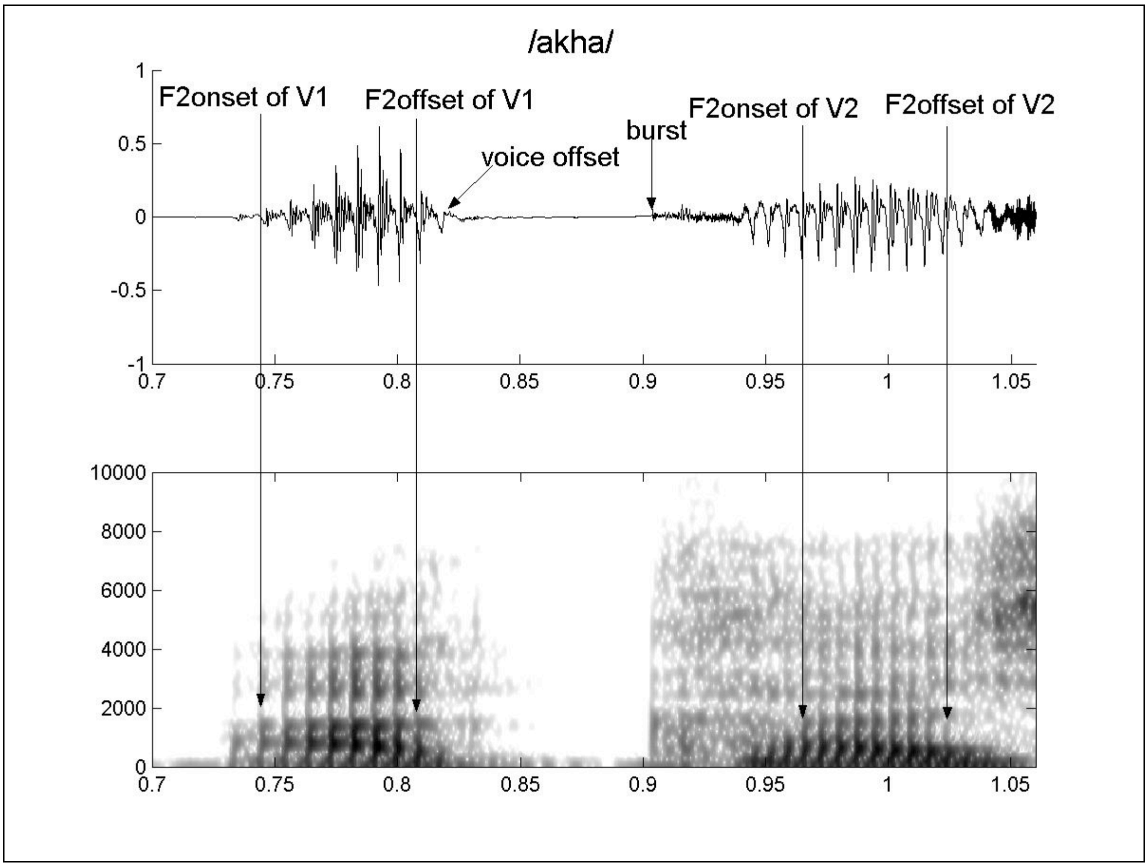

Figure 2: Oscillogram and spectrogramm for /ak^{h}a/ for speaker SH

Acoustic labelling involved a number of problems which will be mentioned briefly. Especially for speaker SH, there was often no closure for /g/, the tongue only approximated the palate without producing a closure. Consequently, it was impossible to measure a burst (cf. figure 3). On the other hand, especially for /k'/ often multiple bursts were detected. In those cases the first one was considered as end of closure for following calculations. Furthermore, speaker HS pronounced the word "suk^{h}uli" without the first /u/: /sk^{h}uli/. In this case F2 onset and offset of V1 could not be labelled. Additionally, because of technical problems with the first recording of /aga/ for speaker HS this recording could not be analysed. So there are only five repetitions of /aga/ for this speaker.

2.2.2 Calculations

In order to constitute a set of parameters that can be used to distinguish the stops from each other the following calculations were carried out.

2.2.2.1 Segmental durations

Sounds can often be distinguished by the duration of certain segments, either preceding or following the particular sound, or by the duration of certain subcomponents of the sound itself. A voiced stop, for example, normally has a longer voicing into closure than a voiceless stop.

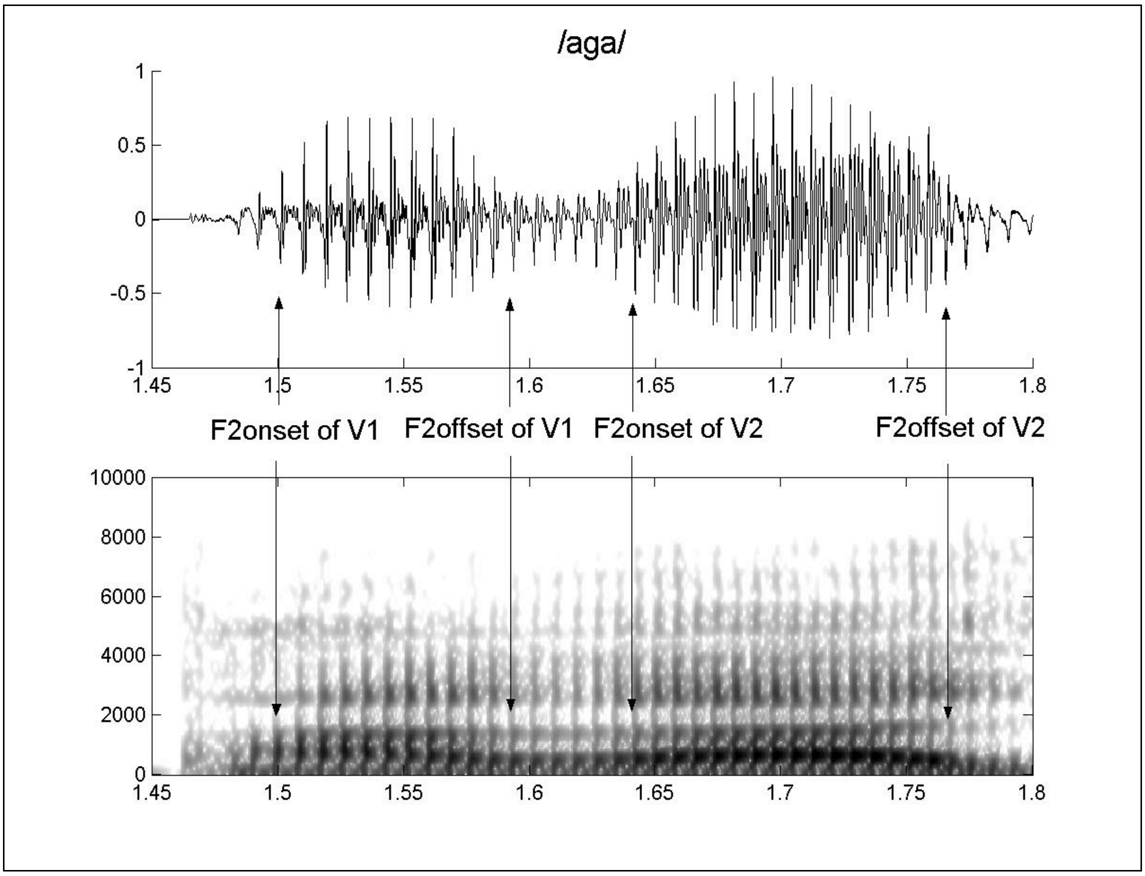

Figure 3: Oscillogram and spectrogramm for /aga/ for speaker SH

The following durations were analysed:

- duration of V1: F2 offset$_{V1}$ - F2 onset$_{V1}$,
- voicing into closure: voice offset - F2 offset$_{V1}$,
- closure duration: burst - F2 offset$_{V1}$,
- voice onset time: F2 onset$_{V2}$ - burst (Klatt 1975),
- duration of V2: F2 offset$_{V2}$ - F2 onset$_{V2}$,
- duration of the complete VCV-sequence: F2 offset$_{V2}$ - F2 onset$_{V1}$.

Furthermore, because the VCV-durations might differ depending on the stop, the percentages of the durations of V1, closure and V2 in relation to the VCV-duration were calculated.

2.2.2.2 Movement amplitude

The movement amplitude is the distance the tongue travels during a given interval. This parameter can tell, for example, how much the tongue moves during closure. It was calculated as the integral of the tangential velocity with the following formula:

movement amplitude = sum(tangential velocity/sampling rate)

The following movement amplitudes were calculated:

- movement amplitude during V1,
- movement amplitude during closure,
- movement amplitude during V2,
- movement amplitude during the VCV-sequence.

2.2.2.3 Euclidean distance

The Euclidean distance is the straight line distance between two points. It differs from movement amplitude in that it is not the way the tongue really moves along but the way it should move if it was taking the shortest path.

The Euclidean distance was calculated via the following formula:

$$\textit{Euclidean distance} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

with x_1 and y_1 being the coordinates of the starting point and x_2 and y_2 being the coordinates of the endpoint.

The following Euclidean distances have been calculated:

- Euclidean distance during V1,
- Euclidean distance during closure,
- Euclidean distance during V2,
- Euclidean distance during the VCV-sequence.

2.2.2.4 Quotients of Euclidean distance and movement amplitude

To find out to which degree the path is curved the quotient of Euclidean distance and movement amplitude has been calculated. This ratio cannot exceed 1, since the Euclidean distance cannot be longer than the movement amplitude. If the result is near 1 this means that the tongue is taking a nearly direct way, whereas if the number is very small the tongue moves in a big loop (Löfqvist 2002).

The quotients follow from what has been measured for movement amplitudes and Euclidean distances.

2.2.2.5 Tangential velocities

Velocities at certain points can also characterise the movement and consequently a sound. For example, there is normally one velocity peak halfway between the middle of a vowel and closure onset. At closure onset, the velocity decreases extremely, so there should be a velocity minimum. If, however, the minimal velocity at that point is a lot higher for one stop than for another this could mean that there is no real closure for the first stop.

Peak and minimal velocities, which means the highest and the lowest velocity during the following sequences have been determined:

- from beginning to end of V1,
- from closure onset to closure offset,
- from beginning to end of V2,
- from beginning to end of the complete VCV-sequence.

Furthermore, the difference between peak velocity and minimal velocity for the whole sequence was calculated. This value tells something about velocity differences during the trajectory. If it is very high, the movement might be rather abrupt, whereas if it is rather small, the movement should be quite even.

2.2.2.6 Tongue position at closure onset

Velar stops are produced in the velar region, however, they can differ in the exact place where the stop is produced. In German, for example, the aspirated velar stop is produced more fronted in an /i/-context than in other contexts. Therefore the x-coordinates of closure onset (F2 offset of V1) were determined.

2.3 Parameter catalogue

After all the measurements had been taken, 31 parameters were set up that might be involved in contrasting the three stops. In the table below the parameters are grouped into four classes according to the segment they refer to.

Table 2: Parameters

a) VCV-movement
1. duration
2. movement amplitude
3. Euclidean distance
4. Euclidean distance/movement amplitude
5. peak velocity
6. minimal velocity
7. peak velocity - minimal velocity
b) V1
8. duration of V1
9. movement amplitude of V1
10. Euclidean distance of V1
11. Euclidean distance/movement amplitude
12. percentage of VCV-duration
13. peak velocity during V1
14. minimal velocity during V1
c) V2
15. duration of V2
16. movement amplitude of V2
17. Euclidean distance of V2
18. Euclidean distance/movement amplitude
19. percentage of VCV-duration
20. peak velocity during V2
21. minimal velocity during V2
d) stop closure
22. closure duration
23. movement amplitude of closure
24. Euclidean distance of closure
25. Euclidean distance/movement amplitude
26. percentage of whole duration
27. peak velocity during closure
28. minimal velocity during closure
29. position: x-value of closure onset
30. voicing into closure
31. VOT

The aim of this study is to find out to which degree these parameters are used to mark the contrast between the stops. In order to do this, one has to make the parameters comparable. For example, to find out whether voicing into closure or movement amplitude during V1 is more important to characterise /k'/ and to set it apart from /k^h/, one has to develop a scale which is independent from value and measuring unit.

In order to do this, the minimal and maximal values of each parameter, independent of the consonant were set to 0 and 100, respectively, and the values in between were converted into values on this scale. This was done separately for each speaker. To reduce the influence of outliers, the means of the three highest and the three lowest values were taken as maximal and minimal values for each parameter. For example, the three highest values of velocity for SH are 19.7492, 19.3158 and 19.0682cm/s, the minimal values are 0.2739, 0.4157, 1.7605cm/s. The mean value for the maxima, 19.3777, was set to 100, the mean for the minima, 0.8167 was set to 0. For all the values in between the two a place on the scale was calculated. For /k'/ in /ak'a/ in the third repetition, which was 15.7507cm/s, this meant that it now was 80.4589 on the scale. This procedure can be seen in the following table:

Table 3: Conversion of measured values into scale values

measured values:	0.8167cm/s	15.7507cm/s	19.3777cm/s
scale values:	0	80.4589	100

After all the measured values had been converted into values on this neutral scale they were grouped according to consonants and parameters. For each parameter and consonant the arithmetic mean was calculated. Now the importance of a single parameter for the characterisation of a consonant could be estimated. Parameters that have a very high or very low scale value, which is, following from that, close to maximum or minimum are characteristic for the consonant, whereas parameters that have an average value are less important.

To find out how important a parameter is for marking the contrast between two consonants, the difference between the arithmetic means of scale values of two consonants was calculated. To give an example, if one looks at closure duration of speaker HS, the mean value on the scale for /g/ is 20.7692, the one for /k'/ is 70.9138. The contrast between the two is the difference, 50.1446.

After an analysis of variance the parameters that did not produce a significant difference were excluded, since they are not useful to distinguish among the stops. For the remaining parameters a hierarchy was set up according to the scale value contrast the parameters produced.

3 Results and Discussion

It turned out that some of the parameters are not useful to distinguish among the stops. Those are listed in section 3.1. Furthermore, this section presents some general features of the stops. Section 3.2. will present the hierarchy of parameters that are useful to contrast the stops. Section 3.3. describes temporal and spatial characteristics for the three stops. Section 3.4. deals with differences between the two speakers.

3.1 Similarities of the three stops

There are certain features that are shared by the three stops. The first point is that there is movement during closure. The direction of the movement depends on the vowel context. The tongue moves forward in the vowel contexts /a_a/, /a_i/, /u_a/, /u_i/ and /u_u/. It moves backwards if the vowel context is /a_u/, /i_a/, /i_i/, /i_u/. This means that it moves backwards only if it has to come from a fronted position to a back position or if V1 is /i/. There is very much movement when V1 is /a/ and hardly any if V1 is /i/. For V1=/u/ the loops are a little bigger than for V1=/i/.

Nearly all productions of the stops have their velocity peak during V1. Furthermore, it turned out that the peak velocity during closure and V1 is about equal, the same is true for the minimal velocity during V2.

Similarly, determining loop ways (parameter: Euclidean distance/movement amplitude) did not produce a significant result, neither for closure nor for the vowels. Furthermore, the Euclidean distance and the movement amplitude for the VCV-sequence were about equal for all the stops. From the V1-parameters Euclidean distance did not produce a significant result. In general V1 turned out to be less influencing than V2.

Furthermore, if one looks at position independently of vowel context and speaker, there is no significant difference in the x-coordinates between the consonants. Even if SH produces /g/ significantly further back than /k^h/ (p=0.008), there is no such difference for HS (cf. figure 3 for SH).

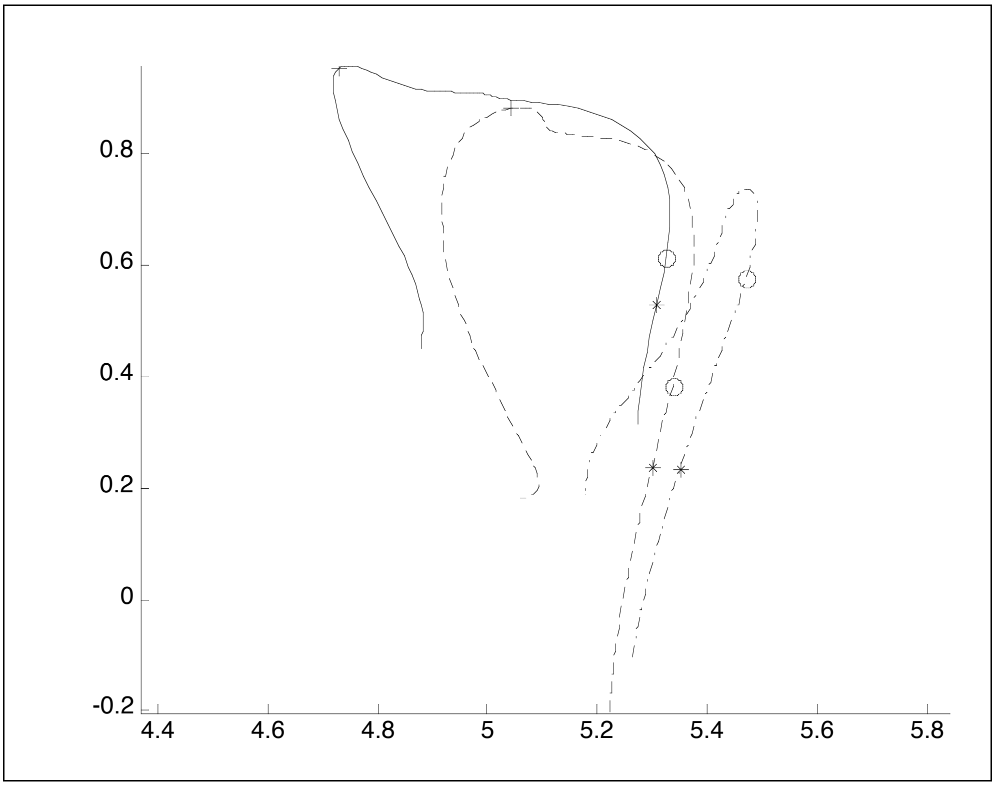

Figure 3: Typical productions of /g/ (dash-dot), /k'/ (solid line) and /k^h/ (dashed) in /a_a/ context. /g/ is produced significantly further back than the other stops. Closure onset (o), burst (+) and velocity peaks (*) are marked. There is no burst for /g/.

However, including vowel context in the analysis, the result is that, if V1 is /i/, closure onset is more forward than if it is /u/ or /a/. This difference is very significant for both speakers. Furthermore, speaker HS produces closure onset more forward in contexts with V1= /a/ than with V1=/u/. For speaker SH it is just the other way round. Those differences are also significant.

3.2 Parameter hierarchy

Some parameters produce a significant difference between the consonants, independently of the speaker. Others are speaker dependent. The later ones were not regarded as distinguishing the three consonants. The parameters that distinguish between the stops independently of the speaker where put on a hierarchy according to the scale discussed above. The following hierarchy of parameters can be established split by speakers:

Table 4: Parameters that distinguish the stops significantly, ordered by contrast on the scale from high to low. The asterisks show the level of significance (: p<0.05, **: p<0.01, ***: p<0.001)*

speaker: SH	**speaker**: **HS**
3 way contrast • closure duration (g<k^h<k’)*** • percentage of complete duration for V2 (k^h<k’<g)*** • duration of V2 (k^h<k’<g)***	**3 way contrast** • closure duration (g<k^h<k’) *** • percentage of complete duration for V2 (k^h<k’<g) *** for /g/ vs. /k’/ and /g/ vs. /k^h/ ** for /k’/ vs. /k^h/ • duration of V2 (k^h<k’<g) *for /g/ vs. /k’/ *** for /g/vs. /k^h/ and /k’/ vs. /k^h/
2 way contrast /g/ vs. /k’/ • voicing into closure (k’<g)*** • closure duration (g<k’)*** • percentage of complete duration for closure (g<k’)*** • percentage of complete movement for V1(k’<g)*** • duration of V1 (k’<g)*** • percentage of complete duration for V2 (k’<g)*** • minimal velocity during closure (k<g)* • duration of V2 (k’<g)*** • duration (g<k’)**	**2 way contrast /g/ vs. /k’/** • closure duration (g<k’) *** • percentage of complete duration for closure (g<k’) *** • percentage of complete movement for V1(k’<g) *** • percentage of complete movement for V2 (k’<g)* • duration of V1 (k’<g) *** • duration (g<k^h<k’)*** • voicing into closure (k’<g) *** • minimal velocity during closure(k<g)* • duration of V2 (k’<g)*

2 way contrast /g/vs. /k^h/ • voicing into closure $(k^h<g)$ *** • VOT $(g<k^h)$ *** • percentage of complete duration for V2 $(k^h<g)$ *** • percentage of complete movement for V1$(k^h<g)$ *** • duration of V1 $(k^h<g)$ *** • duration of V2 $(k^h<g)$ *** • movement amplitude of V2 $(k^h<g)$ *** • closure duration $(g<k^h)$ *** • minimal velocity during closure $(k^h<g)$ ** • percentage of whole duration for closure $(g<k^h{}')$ *** • minimal velocity during V1 $(g<k^h)$ ** • peak velocity during V2 $(g< k^h)$* • movement amplitude for V1 $(k^h<g)$ ** • duration $(g<k^h)$ *	**2 way contrast /g/ vs. /k^h/** • closure duration $(g<k^h)$ *** • percentage of complete movement for closure $(g<k^h)$ *** • VOT $(g<k^h)$ *** • percentage of complete duration for V2 $(k^h<g)$ *** • percentage of complete duration for V1 $(k^h<g)$ *** • duration of V1 $(k^h<g)$ *** • duration of V2 $(k^h<g)$ *** • movement amplitude for V2 $(k^h<g)$ *** • movement amplitude for V1 $(k^h<g)$ *** • voicing into closure $(k^h<g)$ *** • minimal velocity during closure $(k^h<g)$ * • minimal velocity during V1 $(g<k^h)$ * • peak velocity during V2 $(g< k^h)$* • duration $(g<k^h)$ **
2 way contrast /k'/ vs. /k^h/ • VOT$(k'<k^h)$ *** • closure duration $(k^h<k')$ *** • percentage of complete movement for closure $(k^h<k')$ *** • percentage of complete movement for V2 $(k^h<k')$ *** • duration of V2 $(k^h<k')$ *** • movement amplitude of V2 $(k^h<k')$**	**2 way contrast /k'/ vs. /k^h/** • VOT$(k'<k^h)$ *** • duration of V2 $(k^h<k')$ *** • movement amplitude for V2 $(k^h<k')$* • percentage of complete movement for V2 $(k^h<k')$ ** • closure duration $(k^h<k')$ *** • percentage of complete movement for closure $(k^h<k')$ **

Closure duration is the most important parameter, for speaker HS it exceeds voicing into closure in relevance by far. The second and third parameters which enable a three way distinction are percentage of complete duration for V2 and duration of V2. The distinction between /g/ and /k'/ is furthermore built on voicing and V1-parameters, but for speaker HS the V1-parameters are more important than voicing. /g/ and /k^h/ are contrasted by voicing, aspiration and vowel-parameters. Again, speaker HS does not base the distinction primarily on voicing but on other parameters. For /k'/ and /k^h/ V2-parameters are the most important parameters after closure and VOT. The importance of duration of segments for the contrast is illustrated in the diagrams below (figures 5 and 6).

Three conclusions can be drawn from that: Firstly, the "voicing contrast" in Korean is a contrast based not only on voicing but on a conglomerate of parameters of which voicing can be one. Secondly, at least for Korean to base a three way "voicing"-contrast on voicing only seems to be a highly unlikely strategy. Thirdly, even in the distinctions between only two stops, for example /g/ and /k'/, voicing does not necessarily have to be the most important parameter. Looking at it this way, Korean does not contradict to the general tendency in the languages of the world because the contrast is not built primarily on voicing.

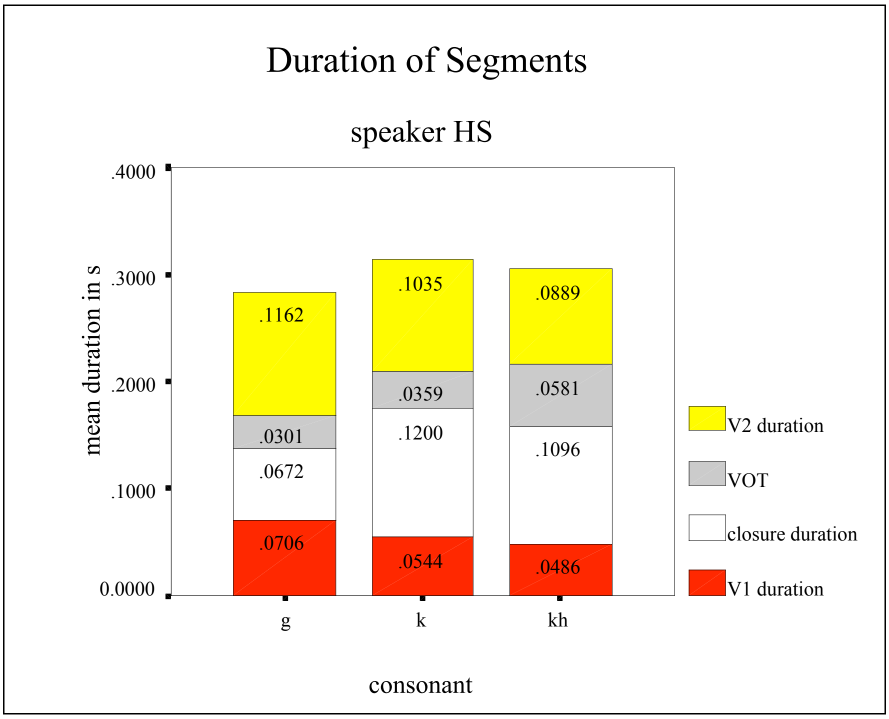

Figure 5: Duration of segments for speaker HS

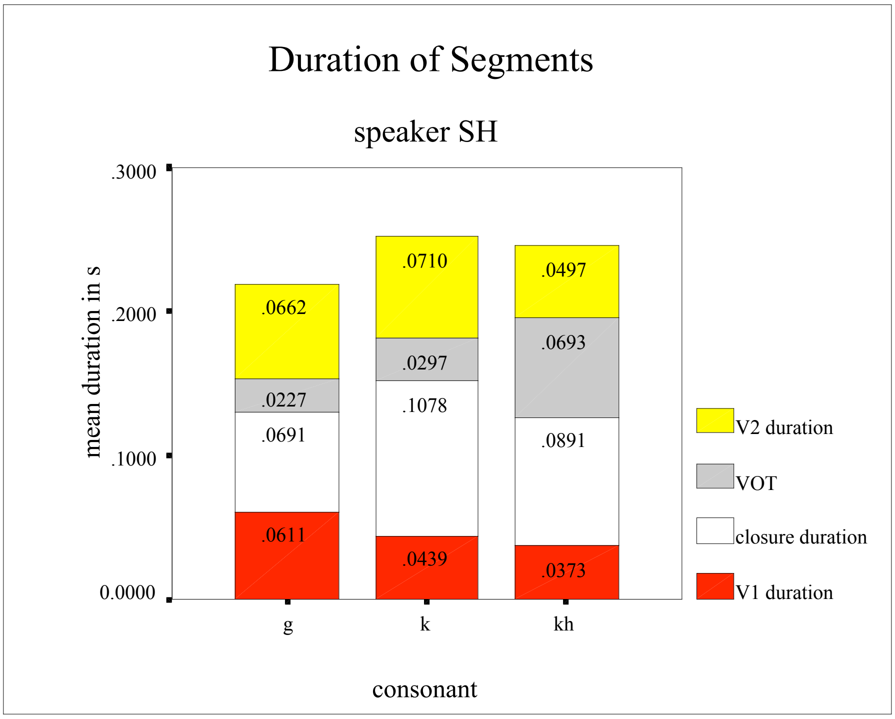

Figure 6: Duration of segments for speaker SH

3.3 Characteristics of the consonants

Each consonant will now be described on the basis of the parameters from the catalogue.

Korean /g/ is often not a real stop, because it is frequently produced without closure. If there is a closure, it is very short, shorter than for the other two consonants. Consequently, the percentage of closure is also very low. Because there is often no real closure, the tongue is not stopped abruptly, so that the minimum velocity during closure is higher than for the other stops. /g/ in general has only very low velocity differences, it has the highest minimum velocity of the three consonants, but the peak velocities are not very high. The second important characteristic of /g/ is its long voicing into closure. Often the consonant is fully voiced. Its VOT is shorter than the ones for the other two consonants. The vowels before and after /g/ are longer than the ones surrounding the other consonants. Following from that, the percentages for both vowels are very high.

The most important characteristic of /k'/ is its long closure, consequently, the percentage of closure is also high. During the long closure, a velocity minimum is reached which is lower than for /g/, so that the two sounds can be distinguished by that. The vowels for /k'/ are shorter than in /g/, even if they are longer than for /k^h/. The percentages of the vowels are consequently also shorter than in the /g/-context. The VOT of /k'/ is considerably shorter than the one for /k^h/, but longer than for /g/. With voicing into closure it is just the other way round.

/k^h/ is an aspirated stop, and this is also its most important characteristic. Its VOT is the highest of all the consonants. Its second important characteristic is the short duration for both vowels, the duration of V1 sets it apart from /g/, the one of V2 from /k'/. Its closure duration is shorter than the one of /k'/ but longer than for /g/.

3.4 Individual use of the parameters by the speakers

The main difference between the speakers is that speaker SH uses voicing into closure and VOT to a much higher degree than the other speaker. Furthermore, for /g/ he often does not produce a real closure. There are a number of other parameters where SH produces a significant difference but HS shows none, however, the levels of significance are normally low:

- duration of V1 for /k'/ vs. /k^h/*,
- minimal velocity during V1 for /g/ vs. /k'/**,
- movement amplitude of V2 for /g/ vs. /k'/*,
- Euclidean distance of V2 for /g/ vs. /k'/** as well as for /k'/ vs. /k^h/***,
- Euclidean distance/movement amplitude for /g/ vs. /k'/**,
- minimal velocity for /g/ vs. /k'/*.

Those parameters are centred around the distinction /g/ vs. /k'/ and may be a result of the different production of /g/ for SH as opposed to HS.

On the other hand, there are also parameters where HS shows a significant difference and SH shows none:

- minimal velocity during V1 for /k'/ vs. /k^h/*,
- percentage of complete duration for closure for /g/ vs. /k^h/***,
- movement amplitude of closure for /g/ vs. /k'/*** as well as /g/ vs. /k^h/**,
- Euclidean distance of closure for /g/ vs. /k^h/*,
- Euclidean distance/movement amplitude for /g/ vs. /k^h/*.

HS strengthens the parameter closure duration by other closure related parameters (2-4 in the list), which SH does not. It is possible that HS, who uses voicing into closure and aspiration to a lower degree, makes up for this by using other parameters to a higher degree than SH to discriminate among the stops clearly enough.

4 Conclusion

The major result of this study is that closure duration is the most important parameter for the distinction of Korean /g/, /k'/ and /k^h/. It is more important than voicing or aspiration because it creates a three way contrast and not only a two way contrast. There are two other parameters that exhibit a two way contrast, namely percentage of complete duration for V2 and duration of V2. Thus the "voicing"-contrast is primarily one not based on a laryngeal characteristic, namely voicing, but on the articulatory characteristics of duration of vowel and closure.

Other important parameters for contrasting /g/ and /k'/ include voicing into closure and duration of V1. For contrasting /g/ and /k^h/ the VOT and a number of characteristics of V1 are important. /k'/ and /k^h/ differ primarily in VOT.

Speakers seem to apply different strategies in distinguishing their stops from each other. In this study, speaker SH used VOT and voicing more intensively than speaker HS, who used other parameters.

Even if significant differences between the parameters could be found, this does not imply automatically that those parameters are used by the hearer to discriminate among the sounds. The parameters simply describe the production of the stops.

So far, this study has treated the parameters as being independent of vowel context which, however, they are not. For this reason, the results are only partly reliable and have to be looked at in greater detail.

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The interaction of nasal substitution and reduplication in Ponapean*

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1 Introduction

The pattern of correspondence relations found between the reduplicant (i.e., the reduplicated affix) and the base in Ponapean prefixal CVC reduplication presents a challenge for Optimality Theory, and, specifically for the version of it known as Correspondence Theory which was originally developed by McCarthy & Prince (1995) for the analysis of reduplication. Consider the data in (1).[1]

(1) Correspondence Relations in Ponapean CVC reduplication

Base	Underlying *Reduplication*	Surface *Reduplication*	Consonant *Correspondence*	*Gloss*
a. linenek	/RED + linenek/	[lil.linenek]	Base /n/ -- Red [l]	'protective'
b. sɛl	/RED + sɛl/	[sɛn.sɛl]	Base /l/ -- Red [n]	'tied'
c. tit	/RED + tit/	[tin.tit]	Base /t/ -- Red [n]	'build a wall'
d. nenek	/RED + nenek/	[nen.nenek]	Base /n/ --Red [n]	'do adultery'
e. net	/RED + net/	[netVnet]	Base /t/ -- Red [t]	'smell'
f. setik	/RED + setik/	[setVsetik]	Base /t/ -- Red [t]	'quick'
g. tune	/RED + tune/	[tun.tune]	Base /n/ --Red [n]	'tie together'

Of particular interest in this paper are cases like (1b) and (1c) which illustrate the phenomenon of nasal substitution whereby a nasal occurs in the output (shown under 'Surface Reduplication') even though there is no triggering nasal in the input. Specifically, in (1b), [l]

* Acknowledgment: This paper develops an analysis of Ponapean reduplication first presented in Davis (1997); various aspects of it are also discussed in Davis (2000). A version of this paper was presented at the Graz Reduplication Conference in November 2002 and I would like to thank Laura Downing, John Frampton, Bernhard Hurch, Nicole Nelson, Patricia Shaw, and Cheryl Zoll for their comments at the conference, as well as Karen Baertsch, Jill Beckman, Daniel Dinnsen, Beverley Goodman, Anna Lubowicz, John McCarthy, Jaye Padgett, Philip Spaelti, and Rachel Walker for their comments on various aspects of this paper. The usual disclaimers apply.

1 The Ponapean data cited in this paper come from Rehg and Sohl (1981), Rehg (1984), Blevins and Garrett (1992), Goodman (1995), and Takano (1996). The reduplication marks the durative aspect, and the CVC prefixal data discussed in this paper represents only one subpattern of the durative reduplication process. In the reduplication examples in (1) and elsewhere in this paper I specifically indicate the consonant correspondence of the final consonant of the reduplicant. V indicates an epenthetic vowel whose surface quality depends on various factors. The period shown between the two consonants signifies a syllable boundary. In all the examples, the boundary between the reduplicant and the base is also a syllable boundary. If the base contains more than one syllable I do not show the syllabification of the base since it is not of direct relevance. However, given universal syllable principles, along the lines of Prince and Smolensky (1993), an intervocalic consonant would syllabify as the onset of the syllable with the following vowel.

is expected in the coda of the reduplicated prefix, but [n] is realized instead. Similarly, in (1c), [t] is expected in the coda of the reduplicated prefix, but [n] is realized in its place.

Now, given the underlying reduplicative forms shown in (1), a particular challenge for a correspondence theory analysis is to account for the data in (1c-e) in a unified way. There is an interesting lack of parallelism between the output of (1c) and (1d-e). In (1c), if the featural identity of the CVC reduplicant were a perfect reflection of the base, we would expect the output [tit.tit]. The actual output is [tin.tit] as shown with nasal substitution. Thus, the correspondent of the base-final /t/ surfaces as [n]. On the other hand, (1e) is quite different. If the featural identity of the CVC reduplicant were a perfect reflection of the base we would expect the output [net.net]. The actual surface output, however, has an inserted vowel, [netVnet]. The problem that is posed for a correspondence theory analysis is why isn't the surface form for (1e) [nen.net], especially since a geminate nasal is possible as seen by the output of (1d) and since a base-final /t/ can have [n] as a correspondent as in (1c)? That is, why doesn't the base-final /t/ in (1e) have the correspondent [n] in the reduplicant like the form in (1c)? Or, to put it the other way around, why isn't the output for (1c) [titVtit] with an epenthetic vowel, parallel to (1e)?[2] In order to see the difficulty that data like (1c) and (1e) present for Correspondence Theory, I will review in Section 2 the analysis of Takano (1996) which is unable to account for the lack of parallelism in these data. In Section 3 I will offer an analysis of Ponapean CVC reduplication that makes reference to a sympathetic candidate along the lines of the proposal of McCarthy (1997, 1999). While McCarthy's proposal has remained controversial, the analysis that I offer not only accounts for data like in (1c) and (1e) in a unified way, it also efficiently expresses the generalization regarding the occurrence of nasal substitution. In this way, sympathy theory provides insight into the analysis of Ponapean CVC reduplication.

2 Previous analysis

In this section I will present the relevant aspects of Takano's (1996) analysis of Ponapean CVC reduplication. I focus on Takano's analysis because it highlights the difficulty that an optimality theoretic analysis faces in accounting for Ponapean CVC reduplication. I also present her analysis since I will incorporate various aspects of it into my own analysis in Section 3.[3] In relating her analysis we will see that, though it accounts for much of the CVC reduplication data, it is unable to account for the lack of parallelism witnessed in the reduplication of a form like /tit/ as [tintit] in (1c) and /net/ as [netVnet] in (1e). Takano's analysis predicts that /tit/ should wrongly reduplicate as [titVtit]. The forms in (1c) and (1e) motivate an analysis that I offer in terms of a sympathetic candidate in Section 3.

Takano offers the following relevant constraints in (2) for the analysis of Ponapean CVC reduplication.

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[2] It seems quite reasonable that the lack of vowel epenthesis in the output of (1c) might have to do with geminate integrity. However, given that the underlying reduplication, /RED + tit/, has no geminate, there is not necessarily a violation of geminate integrity in the output [titVtit]. A major facet of the correspondence theory analysis I will propose in Section 3 is that the correct output of a form like (1c) is faithful to a sympathetic candidate that is fully prosodified containing a geminate and a CVC reduplicant that is featurally faithful to its base, that is *tit.tit*.

[3] Space limitations restrict me from discussing other analyses of Ponapean reduplication such as that of Spaelti (1997) and Kennedy (2002). Both these analyses encounter problems in dealing with the lack of parallelism between (1c) and (1e). See Davis (2000) for a discussion of Spaelti (1997).

(2) Constraints
 a. *μ[-son] -- Obstruents cannot be moraic.
 b. Ident-BR(son) -- A reduplicant correspondent of a base segment must have the same sonorant feature specification.
 c. RED=Affix (RED=$\sigma_{\mu\mu}$ or RED=CVC) -- The reduplicant is an affix. (Other constraints will restrict the reduplicant to the size of a single CVC syllable.)
 d. Ident-BR(nasal) -- A reduplicant correspondent of a base segment must have the same nasal feature specification.

The constraint in (2a) has the effect of disallowing obstruents from being realized in coda position (cf. Goodman 1995, Zec 1995). With the exception of some loanwords and exclamations, (2a) is inviolable (undominated) in Ponapean. (This assumes that word-final consonants are extraprosodic. See Goodman 1997 and Davis 2000 for discussion.) The other three constraints in (2) are not undominated. The two Ident constraints in (2b) and (2d) assure featural identity between corresponding segments in the base and reduplicant with respect to the features [sonorant] and [nasal]. The constraint in (2c), RED=Affix, has been proposed by McCarthy & Prince (1994). This constraint restricts the size of a reduplicant to a single syllable because of another constraint noted by McCarthy & Prince that the phonological exponent of an affix cannot be longer than a syllable. The specific realization of the reduplicant as a heavy CVC syllable (as opposed to a CV syllable) would be due to the interaction of other relevant constraints, the full discussion of which is beyond the scope of this paper.[4] Even though Takano (1996) refers to the constraint in (2c) as RED=$\sigma_{\mu\mu}$, for purposes of clarity I will refer to it as RED=CVC. A form like that in (1e) with an epenthetic vowel between the final consonant of the reduplicant and the initial consonant of the base is viewed as having a violation of (2c) on the interpretation that the reduplicant in (1e) surfaces as two syllables.

Given the constraints in (2), we can consider the constraint ranking and tableaux for the forms in (1c)-(1e). I show how Takano's analysis fails to account for the lack of parallelism between (1c) and (1e) resulting in a ranking paradox in the evaluation of candidates for these forms.

First, consider the tableau for (1d) in (3), which is the reduplicated form of /nenek/. The tableau shows the four constraints in (2).

(3) /nenek/ --- [nen-nenek] ‘do adultery’ (1d)

/RED+ nenek/	*μ[-son]	Ident-BR(son)	RED=CVC	Ident-BR(nas)
☞ a. nen-nenek				
b. nenVnenek			*!	
c. net-nenek	*!	*		*

In (3), the actual output [nen-nenek], (3a), is shown with the two competitors in (3b) and (3c). (3a) does not violate any of the constraints in (2), unlike the other two candidates. Thus, (3a) surfaces as the winner. (3a) displays perfect identity with respect to features between the phonemes of the CVC reduplicant and the corresponding phonemes in the base. (3b) violates

4 Such constraints would include Max-BR and NoCoda as well as RED=Affix. This follows McCarthy and Prince (1999) in the view that there are no constraints that specify a reduplicative template. The shape of the reduplicant emerges from the relevant ranking of constraints like those just mentioned. For clarity and ease of reference I will make use of RED=CVC, but this should be understood as a shorthand for a series of constraints that normally select a CVC reduplicant as optimal.

RED=CVC while (3c) violates undominated *μ[-son] among other constraints. Since the actual candidate, (3a), does not violate any of the relevant constraints, the tableau in (3) does not provide crucial evidence for the ranking among the constraints since there is no constraint conflict. Any ranking of the four constraints in (3) would result in (3a) being the winning candidate. Still, it is assumed that *μ[-son] is highest ranking since it is inviolable in Ponapean.

Takano (1996) shows the ranking between the constraints RED=CVC and Ident-BR(nasal) by considering the reduplication of (1b), /sɛl/ 'tied', in the tableau in (4).

(4) /sɛl/ --- [sɛn-sɛl] ‘tied’ (1b)

/RED + sɛl/	RED=CVC	Ident-BR(nasal)
☞ a. sɛn-sɛl		*
b. sɛl V sɛl	*!	

(4) shows a conflict between RED=CVC and Ident-BR(nasal). Candidate (4a) respects RED=CVC but violates Ident-BR(nasal) since the [n] of the reduplicant corresponds with the nonnasal [l] of the base. On the other hand, (4b) respects Ident-BR(nasal) but violates RED=CVC since the reduplicant surfaces with an epenthetic vowel. Given that (4a) is the winner, then RED=CVC must outrank Ident-BR(nasal) as shown in (5).

(5) RED=CVC >> Ident-BR(nasal)

One realistic candidate not shown in the tableau in (4) is the faithful candidate [sɛl-sɛl]. According to Takano (1996), this candidate is ruled out by the high-ranking constraint No-LC-Link which disallows a place-linked cluster of a liquid followed by a homorganic consonant. Takano proposes this constraint based on a constraint in Itô, Mester, & Padgett (1995) that disallows linked voicing between a sonorant segment and a following consonant. In Takano's analysis, No-LC-Link is higher ranked than Ident-BR(nasal) and so the faithful output [sɛl-sɛl] does not surface.[5]

Given the ranking in (5), let us now consider the ranking between Ident-BR(sonorant) and RED=CVC in Takano's analysis. The crucial example is /net/ in (1e). Tableau (6) shows the constraint evaluation for the possible reduplicated forms.

(6) /net/ --- [netVnet] ‘smell’ (1e)

/RED+ net/	*μ[-son]	Ident-BR(son)	RED=CVC	Ident-BR(nasal)
a. net-net	*!			
☞ b. netVnet			*	
c. nen-net		*!		*

The completely faithful candidate [net-net] in (6a) is eliminated because it violates the undominated constraint *μ[-son]. The competition then is between (6b) and (6c). If the Ident-BR(sonorant) constraint were ignored in Tableau (6), the expected winner would be (6c) given the ranking shown in (5). However, (6c) is not the winner. This means that there must be some constraint that (6c) violates that is higher ranking than the RED=CVC constraint

5 In the analysis I offer in Section 3, [sɛl-sɛl] is ruled out because it violates the undominated constraint Coda Condition (CodaCon) in the sense of Itô (1986) whereby a coda consonant must share place features with a following onset in order to surface. It is assumed that the cluster [l.s] in Ponapean cannot share place features.

which (6b) violates. According to Takano, the relevant constraint that (6c) violates is Ident-BR(sonorant). (6c) violates this constraint since the sonorant [n] of the reduplicant corresponds with the nonsonorant [t] of the base. (6b), according to Takano, respects the Ident-BR(sonorant) constraint. Given the ranking established in (5), Ident-BR(sonorant) and RED=CVC are in conflict. The fact that (6b) is the winner constitutes a ranking argument that the constraint it violates, RED=CVC, must be lower ranked than Ident-BR(sonorant) which (6c) violates. Thus the ranking in (7) is motivated.

(7) Ident-BR(sonorant) >> RED=CVC

Given the constraint ranking established in (5) and (7), an interesting problem arises for Takano's analysis when we consider the evaluation of candidates for forms like that in (1c), /RED + tit/. As shown by the tableau in (8), the ranking in (7) selects an incorrect output (indicated by ☛ in the tableau).

(8) /tit/ --- [tintit] ‘build a wall’ (1c)

/RED+ tit/	*µ[-son]	Ident-BR(son)	RED=CVC	Ident-BR(nasal)
a. tit-tit	*!			
☛ b. titVtit			*	
c. tin-tit		*!		*

The completely faithful candidate, [tit-tit], in (8a) is eliminated because it violates undominated *µ[-son]. The choice then is between (8b) and (8c). Given the ranking established in (7), the candidate in (8b) is wrongly predicted as the winning candidate since it violates only lower-ranked RED=CVC. The tableau in (8) makes clear the lack of parallelism between the data in (1c) and (1e). The constraint ranking of Ident-BR(sonorant) >> RED=CVC cannot account for the correct reduplication of /tit/. However, the correct output of [tintit] can be determined if the ranking of RED=Affix and Ident-BR(sonorant) were reversed, as in (9).

(9) RED=CVC >> Ident-BR(sonorant)

The tableau in (10) shows how this ranking results in the correct output for the reduplication of /tit/.

(10) /tit/ --- [tintit] ‘build a wall’ (1c)

/RED+ tit/	*µ[-son]	RED=CVC	Ident-BR(son)	Ident-BR(nasal)
a. tit-tit	*!			
b. titVtit		*!		
☞ c. tin-tit			*	*

This results in a ranking paradox. The reduplicative output for /tit/ seems to require the ranking in (9) while the reduplicative output for /net/ requires the opposite ranking in (7). Even if we put Ident-BR(sonorant) and RED=CVC in the same constraint block (along the lines of Ní Chiosáin 1995) and passed the outcome on to lower ranking Ident-BR(nasal), a wrong candidate would be predicted, as seen in (11).

(11) /tit/ --- [tintit] 'build a wall' (1c)

/RED + tit/	*µ[-son]	Ident-BR(son)	RED=CVC	Ident-BR(nasal)
a. tit-tit	*!			
☛ b. titVtit			*	
c. tin-tit		*		*!

Consequently, the lack of parallelism between (1c) and (1e) is problematic for Takano's (1996) correspondence theory analysis of Ponapean reduplication.[6] In the following section, I will offer an analysis of Ponapean CVC reduplication that builds on Takano's work but makes use of sympathetic candidates along the lines of McCarthy (1997. 1999).

3 A Sympathetic Analysis

One of the keys for solving the Ponapean reduplication problem in a uniform way without a ranking paradox is to understand why nasal substitution occurs when it does. Nasal substitution occurs in forms like (1b) and (1c). Data like that in (1b) and (1c) are shown in (12) and (13), respectively. In (12), the nasal substitutes for a sonorant and in (13) it substitutes for an obstruent.

(12) Reduplication with nasal substitution (similar to 1b)

Base	Underlying *Reduplication*	Faithful *Redup.*	Surface *Redup.*	Consonant *Correspondence*	*Gloss*
a. sɛl	/RED + sɛl/	sɛl.sɛl	[sɛn.sɛl]	Base [l] - Red [n]	'tied'
b. tar	/RED + tar/	tar.tar	[tan.tar]	Base [r] - Red[n]	'strike'
c. sar	/RED + sar/	sar.sar	[san.sar]	Base [r] - Red [n]	'fade'
d. tilep	/RED + tilep/	til.tilep	[tin.tilep]	Base [l] - Red [n]	'mend'

(13) Reduplication with nasal substitution (similar to 1c)

Base	Underlying *Reduplication*	Faithful *Redup.*	Surface *Redup.*	Consonant *Correspondence*	*Gloss*
a. tit	/RED + tit/	tit.tit	[tin.tit]	Base [t] - Red [n]	'build'
b. sas	/RED + sas/	sas.sas	[san.sas]	Base [s] - Red [n]	'stagger'

6 Even if we posit an analysis that makes use of constraint conjunction along the lines of Smolensky (1997), we would still not be able to account for the difference between (6) and (8). Given the ranking shown in (7), we can account for the problematic case of [tintit] in the tableau in (8) by conjoining two low ranking constraints that the candidate [titVtit] violates and ranking the conjoined constraint higher than Ident-BR(sonorant). Perhaps this conjoined constraint would be as in (i), though there may be some other relevant constraint involved instead of DEP-BR. The ranking of this constraint is shown in (ii)

a. RED=CVC & DEP-BR
b. RED=CVC & DEP-BR >> Ident BR(son) >> RED=CVC (>> DEP-BR)

The candidate [titVtit] in (8b) violates the high-ranking conjoined constraint since it violates both RED=CVC and DEP-BR. The candidate [tintit] in (8c) does not violate either conjunct of the high-ranking conjoined constraint and so would be correctly selected as the winner.
While the conjoined constraint with the ranking shown in (ii) unproblematically accounts for the reduplication of /tit/ as [tintit], the exact same constraint and ranking fails to account for the reduplication of /RED + net/. Here the candidate [netVnet] violates both conjuncts of the high-ranking conjoined constraint whereas the alternative candidate [nennet] respects the conjoined constraint violating lower-ranking Ident-BR(sonorant). Thus the conjoined constraint in (i) with the ranking in (ii) wrongly predicts that [nennet] should be the reduplicated form of /net/.

c.	kak /RED + kak/	kak.kak	[kaŋ.kak]	Base [k] - Red[ŋ]	'able'
d.	pap /RED + pap/	pap.pap	[pam.pap]	Base [p] - Red [m]	'swim'

Nasal substitution does not occur with data like (1e) or (1f), as shown in (14), even though there is nothing phonotactically wrong with a possible output like [nen.net] for (14a) or [sen.setik] for (14b), the latter of which clearly shows nasal substitution. (The possible output [nen.net] for (14a) could be viewed as involving the spreading of the feature nasal from the base. (14b) involves nasal substitution since there is no potential triggering nasal.)

(14) Reduplication without nasal substitution

	Underlying	Faithful	Surface	Consonant	
	Base Reduplication	*Redup.*	*Redup.*	*Correspondence*	*Gloss*
a.	net /RED + net/	net.net	[ne.tV.net]	Base [t] - Red [t]	'smell'
b.	setik /RED + setik/	set.setik	[se.tV.setik]	Base [t] - Red [t]	'quick'

In order to understand when nasal substitution occurs it is necessary to make reference to the column marked 'Faithful Reduplication' in (12)-(14). This column shows what the reduplicated forms would be if the CVC reduplicant were completely faithful to the features of the base. If we assume that the forms under 'Faithful Reduplication' are prosodified, the forms in (12) and (13) are distinct from that in (14) in an interesting way. In (12) and (13) the first syllable of the faithful reduplicated form would end in a moraic consonant while that in (14) would not. Following Goodman (1995) and Takano (1996), syllable-final sonorant consonants can be considered moraic in Ponapean since these are the only type of syllable-final consonants that can surface in Ponapean. (Word-final consonants, though, are considered extraprosodic; see Goodman 1997.) For the forms under 'Faithful Reduplication' in (13), I assume that the coda consonant of the first syllable in these forms would also be moraic since they would be part of a geminate, even though geminate obstruents do not actually surface in Ponapean. The moraic nature of geminates has been specifically argued for in such works as Sherer (1994) and Davis (1994, 1999, 2003). On the other hand, the forms under 'Faithful Reduplication' in (14) would not have a moraic consonant at the end of the first syllable since that syllable ends in a consonant that is neither a sonorant nor part of a geminate.[7]

The proposal that I put forward in this paper is that the forms under 'Faithful Reduplication' in (12)-(14), fully prosodified, can be considered sympathetic candidates, given Sympathy Theory, as developed in McCarthy (1997, 1999), where it is maintained that there can be candidate-to-candidate faithfulness within a single tableau. That is, the form that surfaces (i.e., the winning candidate) aims to maintain some property of a selected failed candidate (referred to as the sympathetic candidate). The sympathetic candidate is fully prosodified since it is a possible output candidate. By positing that the forms under 'Faithful Reduplication' in (12)-(14) constitute sympathetic candidates, these can have an influence on the nature of the actual output. The sympathetic candidate is determined by a selector constraint. The specific selector constraint that picks out the sympathetic candidate for Ponapean CVC reduplication would be Ident-BR which requires feature identity between the phonemes of the base and the corresponding phonemes of the reduplicant. (See McCarthy 1997, 1999 and Itô and Mester 1997 for more details regarding the nature of the selector constraint and how it chooses the sympathetic candidate.) Given this, we can now state the generalization on nasal substitution in (15).

7 The restriction of moraic consonants to those of high sonority or to obstruents that are part of a geminate is not unusual and can be found in languages like Japanese, Hausa, and Italian.

(15) Generalization of Nasal Substitution

Nasal substitution occurs in order to preserve the consonantal moraic structure of the sympathetic candidate.[8]

This generalization captures why nasal substitution occurs in (12) and (13) but fails to occur in (14). As mentioned above, the first syllable of the 'Faithful Reduplication' (i.e. the sympathetic candidate) in (12) and (13) would end in a moraic consonant; the first syllable of the actual reduplicated form in (12) and (13) ends in a moraic nasal consonant through nasal substitution, thus preserving the consonantal mora structure of the sympathetic candidate. On the other hand, the first syllable of the 'Faithful Reduplication' in (14) does not end in a moraic consonant and neither does the actual surface reduplicant. In the remainder of this paper I will show that by reference to a sympathetic candidate a correspondence theory analysis can account for the Ponapean CVC reduplication data without any ranking paradox.

In presenting the sympathetic analysis of Ponapean CVC reduplication, I first consider the reduplication of /sɛl/ 'tied' in (1c) repeated in (12a). As proposed, the sympathetic candidate in Ponapean CVC reduplication is a fully prosodified form with a CVC reduplicant that is featurally faithful to the base. The selector constraint that chooses the sympathetic candidate is Ident-BR. This constraint requires that the features of corresponding segments in the base and reduplicant be identical.

In addition to the selector constraint, we need to posit a sympathy constraint that relates the actual output to the sympathetic candidate. Given the generalization on nasal substitution in (15), the sympathy constraint is one that requires preservation of consonantal moraic structure between the sympathetic candidate and the output candidates. This constraint is stated below in (16) and I will refer to it as the flowered constraint.

(16) Max-μ_c✿-O -- Every consonantal mora in the sympathetic candidate has a correspondent in the output candidate.

The ranking of this constraint is of importance. First, though, I still assume the constraints and their ranking for Ponapean that was established by Takano (1996). This was discussed in Section 2 and is reflected by the tableau in (6). For convenience I repeat this ranking in (17a) where only *μ[-son] is an undominated constraint. There are two other undominated constraints that I refer to in my analysis. These are given in (17b) and (17c)

(17) a. Constraint ranking based on Takano (1996)
*μ[-son] >> Ident-BR(son) >> RED=CVC >> Ident-BR(nasal)
b. Coda Condition (Coda-Con) -- A coda consonant must share the place of articulation features with a following onset consonant.
c. Syllable Contact (SyllCon) -- Avoid rising sonority over a syllable boundary.

The constraint in (17b) has the effect of requiring a coda consonant to share a place of articulation with the following onset consonant. The constraint Syllable Contact (SyllCon) in (17c) was proposed by Bat El (1996) and is further developed by Davis and Shin (1999), and Baertsch (2002) all of whom account for Vennemann's (1988) Syllable Contact Law from the perspective of Optimality Theory. SyllCon disallows a sequence of rising sonority from

[8] Because of data like /par/ 'cut' which reduplicates as [pa.rV.par], and not as [pam.par], the stated generalization on nasal substitution must be restricted so that nasal substitution only applies if the coda consonant has the same place articulator as the following onset. This reflects an undominated Ident-BR(place) constraint. (See Davis 2000 for discussion.)

occurring over a syllable boundary. This constraint is undominated in Ponapean. When a consonant cluster occurs over a syllable boundary there is either falling sonority from the first consonant to the second (as in [sɛn.sɛl] 'tied') or the same sonority in the case of geminates (as in [nen.ne.nek] 'do adultery'); there is never rising sonority.

Let us now consider tableaux showing data like that in (12) and (13) involving nasal substitution. The tableau in (18) shows the reduplication of /sɛl/ as [sɛnsɛl] from (12a). The candidates are shown with their moraic structure. The designated faithfulness constraint (Ident-BR) is set off to the right of the doubled lines. The sympathetic candidate is shown with the flower icon in (18a). Regarding the flowered constraint, the tableaux below will show it is ranked above Ident-BR(sonorant) but below the undominated constraints.[9]

(18) /sɛl/ --- [sɛnsɛl] 'tied' (12a)

/RED + sɛl/	*μ[-son] CodaCon SyllCon	Max- μ_c ✿-O	Ident- BR(son)	RED= CVC	Ident- BR(nasal)	Ident- BR
μ μ μ ✿ a. s ɛ l. s ɛ l	*! (CodaCon)					√
μ μ μ ☞ b. s ɛ n. s ɛ l					*	*
μ μ μ c. s ɛ.l V.s ɛ l		*!		*		*

The tableau in (18) does not show the critical ranking of the flowered constraint, Max-μ_c✿-O. It does correctly select [sɛnsɛl] in (18b) as the winner since it only violates low-ranked Ident-BR(nasal). The completely faithful candidate in (18a) is eliminated because it violates undominated CodaCon. This assumes that in Ponapean there cannot be a place-linked cluster between a liquid and a following (non-identical) consonant. This assumption is reasonable under the view that the relevant feature distinguishing the liquids, such as [±lateral], is located under the Place Node (cf. Blevins 1994). Thus, while /l/ and /s/ are both coronal, they cannot share the same Place Node since [s] cannot have the feature [lateral], given that there are no lateral obstruents in Ponapean. Candidate (18c) violates the flowered constraint since the moraic consonant of the sympathetic candidate in (18a) has no moraic correspondent in (18c). However, since (18c) also violates RED=CVC it does not provide crucial evidence for the ranking of the flowered constraint given that RED=CVC was shown by Takano (1996), as seen in (4), to be higher-ranked than Ident-BR(nasal), which (18b) violates. Candidate (18b) which respects the flowered constraint thus emerges as the winner since it violates only low-ranked Ident-BR(nasal).[10]

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9 There is a technical issue as to whether the candidate in (18c) violates the selector constraint, given that the features of the epenthetic vowel do not surface in the base. That is, do inserted or deleted features between two corresponding strings constitute a violation of Ident-Feature constraints? Or, are Ident-Feature constraints only violated when there is a change of a feature between two strings (as opposed to an insertion or deletion)? Here I will assume that the insertion or deletion of a feature results in an Ident-Feature violation. Consequently, (18c) does not satisfy the selector constraint, Ident-BR.

10 One candidate that is not considered in (18) is [sɛllɛl] where the /s/ of the base totally assimilates to the final consonant of the reduplicant. In the Ponapean CVC reduplication data, the base consonants never undergo alternations; only reduplicant consonants do. I assume that this reflects the universal ranking of Ident-Root over Ident-Affix as discussed in McCarthy and Prince (1995). Consequently, I will not consider candidates that show an alternation in the base.

Crucial evidence for the ranking of the flowered constraint is provided by the evaluation of candidates for the reduplication of /tit/ 'build a wall'. Recall that this form was problematic for Takano's analysis as seen in the tableau in (8). As shown there, Takano's analysis predicts that /tit/ should reduplicate as [titVtit] rather than the actual [tintit]. It is by eliminating [titVtit] that the flowered constraint Max-μ_c✿-O plays a crucial role. This is shown in the tableau in (19).

(19) /tit/ --- [tin-tit] 'build a wall' (13a)

/RED + tit/	*μ[-son] CodaCon SyllCon	Max-μ_c ✿-O	Ident- BR(son)	RED= CVC	Ident- BR(nasal)	Ident- BR
μ μ μ ✿ a. t i t. t i t	*! (*μ[-son])					√
μ μ μ ☞ b. t i n. t i t			*		*	*
μ μ μ c. t i. t V. t i t		*!		*		*

In the tableau in (19), the sympathetic candidate (19a) is eliminated because it violates undominated *μ[-son]. The choice then is between (19b) and (19c). If the flowered constraint were not there, (19c) would be the expected winner. This is because (19b) violates Ident-BR(son) which is higher-ranked than the constraint violated by (19c), RED=CVC. Since (19b) is the actual winner, then the constraint Max-μ_c✿-O which (19c) violates must be higher-ranked than Ident-BR(son). (19c) violates Max-μ_c✿-O because the moraic consonant of the sympathetic candidate in (19a) has no consonantal moraic correspondent in (19c). On the other hand, (19b) respects it since it preserves the moraicity of the geminate consonant of the sympathetic candidate; it preserves it through nasal substitution. Since (19b) is the winning candidate, the flowered constraint must be ranked higher than Ident-BR(son).

The use of the flowered constraint and the sympathetic candidate captures quite well why nasal substitution occurs for data like in (13) where one would expect a geminate obstruent if reduplication were faithful, as in the hypothetical [tittit] for the reduplication of /tit/. Nasal substitution occurs so as to preserve the moraic nature of the consonant in the expected faithful reduplicative candidate without violating the undominated constraint against moraic obstruents. The actual output is dependent on the prosodified sympathetic candidate and the flowered constraint (Max-μ_c✿-O) insightfully expresses this dependency.

That reference to the consonantal moraic nature of the sympathetic candidate is of importance to the understanding of Ponapean CVC reduplication can be seen in data like (14) where the prosodified sympathetic candidate as reflected in (28a) does not have a moraic consonant. For example, in (28a) the coda [t] of the reduplicant is neither a sonorant nor the first part of a geminate. Consequently, nasal substitution does not occur in the reduplication of forms like in (14) because the prosodified sympathetic candidate would not contain a moraic consonant. This is shown in the tableau in (20).

(20) /net/ --- [netVnet] ‘smell’ (14a)

/RED + net/	*μ[-son] CodaCon SyllCon	Max-μ_c ✿-O	Ident- BR(son)	RED= CVC	Ident- BR(nasal)	Ident-BR
μ μ ✿ a. ne t. ne t	*! (SyllCon)					√
μ μ μ b. ne n. n e t			*!		*	*
μ μ μ ☞ c. n e.tV.net				*		*

Given that the sympathetic candidate in (20a) contains no moraic consonant, the designated faithfulness constraint, Max-μ_c✿-O, plays no role. The other constraints, whose rankings have already been established, select [netVnet] in (20c) as most harmonic. (20b) is eliminated because it violates Ident-BR(sonorant) which outranks RED=CVC. (20a) shows the role of SyllCon. This candidate does not violate *μ[-son] since the obstruent is not moraic. It also does not violate CodaCon since the cluster of [t.n] could be reasonably considered a place-linked cluster. The undominated constraint that (20a) violates is SyllCon since there is rising sonority between [t] and [n] over the syllable boundary. (20c) is the winner since it only violates lower ranked RED=CVC.

The analysis that I have presented is able to account for the difference between the reduplication of /tit/ as [tin.tit] and /net/ as [ne.tV.net]. Recall from Section 2 that Takano was unable to account for both these forms. As seen in the tableaux in (6) and (8) Takano's analysis predicts that /tit/ should reduplicate as [ti.tV.tit]. Thus, my analysis is superior empirically in being able to cover both these types of data. Moreover, I would maintain that the analysis with the sympathetic candidate and flowered constraint accurately captures the generalization regarding nasal substitution in (15), that nasal substitution occurs to preserve the mora structure of the candidate that has a CVC reduplicant that is featurally faithful to the base. Takano's analysis falters in that it does not consider the moraic structure of the reduplicant. Furthermore, my analysis extends readily to the complete range of the CVC reduplication data such as that in (1a) and (1g). It is these forms that I now consider.

Let us consider data like that in (1a) presented in (21).

(21)	Underlying	Faithful	Surface	Consonant	
Base	*Reduplication*	*Redup.*	*Redup.*	*Corresp.*	*Gloss*
a. linenek	/RED + linenek/	lin.linenek	[lil.linenek]	n.l → l.l	‘oversexed’
b. lirooro	/RED + lirooro/	lir.lirooro	[lil.lirooro]	r.l → l.l	‘protective’
c. nur	/RED + nur/	nur.nur	[nun.nur]	r.n → n.n	‘contract’

The data in (21) reflect the case where there is total assimilation between the actual surface output and the sympathetic (segmentally faithful) reduplicative form. This occurs when the two adjacent consonants in the sympathetic candidate are both (coronal) sonorants. Total assimilation in these forms allows for the preservation of the consonantal mora structure of the sympathetic candidate without violating any of the undominated constraints such as CodaCon and SyllContact. The sympathetic candidates for the data in (21) (reflected under the column 'Faithful Reduplication') would have a moraic coda at the end of the first syllable since the consonant at the end of that syllable is a sonorant. Total assimilation occurs so as to respect Max-μ_c✿-O; the sympathetic candidate would be eliminated from consideration since it would violate either inviolable CodaCon or SyllCon. Thus total assimilation, like nasal substitution is motivated by the preservation of mora structure of the sympathetic candidate. The example of /linenek/ in (21) is shown in the tableau in (22).

(22) /linenek/ -- [lil-linenek] ‘oversexed’ (21a)

/RED + linenek/	*μ[-son] CodaCon SyllCon	Max-μ_c ✿-O	Ident-BR(son)	RED= CVC	Ident-BR (nasal)	Ident-BR
μ μ μ μ μ ✿ a. l i n.l i. ne.nek	*! (SyllCon)					√
μ μ μ μ μ ☞ b. l i l.l i. ne.ne k					*	*
μ μ μ μ μ c. l i.nV. l i. ne.nek		*!		*		*

The sympathetic candidate in (22a) is eliminated because it fatally violates the undominated syllable contact constraint given that there is a rise of sonority between [n] and [l] over the syllable boundary. The candidate need not be interpreted as also violating CodaCon since hypothetically the nasal sound could be made with the lateral tongue position. The candidate in (22c) violates the flowered constraint Max-μ_c✿-O because the consonantal mora of the sympathetic candidate has no moraic correspondent in (22c). (22b), the winning candidate, obeys this constraint.

Now let us consider reduplication data like that in (1g) shown below in (23).

(23)	Underlying	Faithful	Surface	Consonant	
Base	*Reduplication*	*Redup.*	*Redup.*	*Corresp.*	*Gloss*
a. tune	/RED + tune/	tun.tune	[tun.tune]	n.t □ n.t	‘tie together’
b. sinom	/RED + sinom/	sin.sinom	[sin.sinom]	n.s □ n.s	‘sink in’
c. kaŋ	/RED + kaŋ/	kaŋ.kaŋ	[kaŋ.kaŋ]	ŋ.k □ ŋ.k	‘eat’
d. nenek	/RED + nenek/	nen.nenek	[nen.nenek]	n.n □ n.n	‘do adultery’
e. rer	/RED + rer/	rer.rer	[rer.rer]	r.r □ r.r	‘tremble’
f. mem	/RED + mem/	mem.mem	[mem.mem]	m.m □ m.m	‘sweet’
g. lal	/RED + lal/	lal.lal	[lal.lal]	l.l □ l.l	‘make sound’

The data in (23) are interesting because they represent a case where the sympathetic candidate is the actual surfacing candidate. This situation arises when the two adjacent consonants in the 'Faithful Reduplication' are either identical sonorant consonants (23d-g) or a nasal homorganic with a following obstruent (23a-c). The example of /tune/ in (23a) is shown in (24) where the only two realistic candidates are the sympathetic candidate in (23a) and the candidate with an epenthetic vowel.

(24) /tune/ --- [tun-tune] ‘tie together’ (23a)

/RED + tune/	*μ[-son] CodaCon SyllCon	Max-μ_c ✿-O	Ident- BR(son)	RED= CVC	Ident- BR(nasal)	Ident-BR
μ μ μ μ ✿ | | | | ☞ a. tu n. tu ne						√
μ μ μ μ | | | | b. tu.nV.tu.ne		*!		*		*

The sympathetic candidate (24a) is the winner because it violates none of the relevant constraints shown in the tableau. The alternative candidate in (24b) violates Max-μ_c✿-O because it does not respect the consonant mora structure of the sympathetic candidate; it also violates RED=CVC since the reduplicant surfaces with an epenthetic vowel. The tableau in (24) is interesting because it shows that the sympathetic candidate can be the winning candidate.

In summary, the sympathetic analysis of Ponapean CVC reduplication accounts for the entire range of CVC reduplication data.[11] The analysis is superior to that of Takano (1996) in that it does not entail any ranking paradox. Moreover, I would maintain that the analysis with the sympathetic candidate and flowered constraint accurately captures the generalization regarding nasal substitution in (15), that nasal substitution occurs in reduplication to preserve the mora structure of the sympathetic candidate. To see this, one need only compare the nasal substitution data in (1b) and (1c), repeated below in (25) to the nonreduplicative affixation data involving suffixation in (26).

(25) Reduplication with nasal substitution (between adjacent coronals)

	Underlying	Faithful	Surface	Consonant	
Base	*Reduplication*	*Redup.*	*Redup.*	*Correspondence*	*Gloss*
a. tit	/RED + tit/	tit.tit	[tin.tit]	Base [t] - Red [n]	‘build’
b. sɛl	/RED + sɛl/	sɛl.sɛl	[sɛn.sɛl]	Base [l] - Red [n]	‘tied’

(26) Affixation with vowel insertion (between two adjacent coronals)

Underlying Representation	*Phonetic Representation*	*Non-occurring Alternative*	*Gloss*
a. /pɔt + ti/	[pɔtVti]	[pɔnti]	‘plant downwards’
b. /sɛl + saŋ/	[sɛlVsaŋ]	[sɛnsaŋ]	‘tied from’

The comparison is instructive because the underlying consonantal sequence in (26a) and (26b) (/t + t/ and /l + s/, respectively) exactly parallels the consonantal sequence under the 'Faithful Reduplication' column in (25). However, in (26), unlike (25), there is no nasal substitution,

[11] The only type of CVC reduplication data not yet mentioned in this paper is a form like /m^{w}op^w/ 'out of breath' which reduplicates as [m^{w}om^w.m^{w}op^w]. This is surprising in that /net/ 'tied' reduplicates as [netVnet] and not as [nen.net]. For the analysis of this form, I follow Takano (1996) and Spaelti (1997) who posit that the output [m^{w}om^w.m^{w}op^w] reflects a high-ranking *Place/Labial constraint. Davis (2000) shows that by incorporating high-ranked *Place/Labial (and *Place/Dorsal), the constraint ranking posited for reduplication also unproblematically handles the somewhat different pattern of nasal substitution found in suffixation.

rather there is just vowel insertion. This is, in fact, what is predicted by the constraint ranking already established as shown by the tableau in (27) which evaluates candidates from the input (i.e., underlying) form of (26a). We add here a low-ranked constraint DEP which militates against inserted segments.

(27) /pɔt + ti/ --- [pɔtVti] 'plant downwards' (28a)

/pɔt + ti/	*μ[-son] CodaCon SyllCon	Max-μ_c ✿-O	Ident-BR(son)	RED= CVC	DEP	Ident-BR
μ μ μ a. p ɔ t ti	*! (*μ[-son])					
μ μ μ b. pɔ n t i			*!			
μ μ μ ☞ c. pɔ tV t i					*	

Since (27) does not involve reduplication, neither the selector constraint (Ident-BR) nor the flowered constraint plays a role. The constraint ranking favors candidate (27c) with an epenthetic vowel.[12] On the other hand, as argued, nasal substitution occurs in (25) so as to preserve the moraic structure of the faithfully reduplicated candidate. This is captured by the sympathy analysis. Previous analyses failed to recognize the role of mora structure in nasal substitution.

In conclusion, the analysis offered for Ponapean accounts for all the CVC reduplication data without having a ranking paradox. By incorporating the sympathetic candidate it accurately captures that the reduplicative output makes reference to a selected prosodified candidate. The ranking established for reduplication applies to the cases of suffixation in (26). There is no need for separate accounts for suffixation and reduplication or for a posible level ordered analysis as in Lombardi (1996). Crucial to the analysis presented here is the view that geminates are moraic as argued by Davis (1994, 1999). While McCarthy's proposal for sympathy, where there is candidate to candidate faithfulness in optimality theory remains controversial, it seems to express precisely the generalization that nasal substitution occurs in Ponapean reduplication in order to preserve the mora structure of a faithfully reduplicated output.

12 It should be mentioned that low-ranked DEP would be irrelevant if it were included in previous tableaux such as (19) where nasal substitution occurs in the reduplicated form. In that tableau, the candidate that violates DEP, (19c), would be eliminated because of its violation of the higher-ranked flowered constraint. Also, in affixation involving identical noncoronals, nasal substitution occurs rather than vowel insertion. An example mentioned by Goodman (1995: 195) is /teelap + peseŋ/ which is realized as [teelam peseŋ] 'to get wider'. An analysis of such forms is presented in Davis (2000), but also see Spaelti (1998) regarding the different patterning of coronals and noncoronals as well as a different conceptualization of Ponapean nasal substitution.

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The independence of phonology and morphology: the Celtic mutations*

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Abstract

One of the most important insights of Optimality Theory (Prince & Smolensky 1993) is that phonological processes can be reduced to the interaction between faithfulness and universal markedness principles. In the most constrained version of the theory, *all* phonological processes should be thus reducible. This hypothesis is tested by alternations that appear to be phonological but in which universal markedness principles appear to play no role. If we are to pursue the claim that all phonological processes depend on the interaction of faithfulness and markedness, then processes that are not dependent on markedness must lie outside phonology. In this paper I will examine a group of such processes, the initial consonant mutations of the Celtic languages, and argue that they belong entirely to the morphology of the languages, not the phonology.

1 Celtic consonant mutations

The initial consonant mutations of the Celtic languages are of great interest in theoretical linguistics because they appear to be (and are frequently argued to be) phonological rules that apply in morphosyntactic rather than phonological environments. Within phonological theory they are interesting also because many of the individual mutations have different effects on different classes of sounds. Thus, for example, Eclipsis in Irish voices voiceless stops (e.g. p → b) and nasalizes voiced stops (e.g. b → m). The Soft Mutation in Welsh voices voiceless stops (e.g. p → b) and spirantizes voiced stops (e.g. b → v). The processes are thus not uniform and only partially predictable. In derivational phonology, devising phonological rules to account for the mutations is challenging, but not impossible. Derivational phonology allows its rules to be arbitrary and independent of universal markedness principles. But the advent of OT has forced a rethinking of the nature of phonological processes: according to the new theory, phonological processes are predicted to result from the interaction of markedness and faithfulness. In this paper I will argue that since the morphosyntactically conditioned consonant mutations of Celtic do not result from that interaction, they cannot be phonological. Instead, the mutations are best regarded as being exclusively in the domain of the morphology, not the phonology at all. I will argue that, like inflected forms, mutated forms are listed separately in a word-based lexicon as allomorphs, and that the selection of mutated allomorphs is determined by a form of government similar to that determining the distribution of Case.

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1.1 The effects of the mutations

The effects of the mutations vary from language to language. For example, as shown in (1), Irish has two mutations, Lenition and Eclipsis. Lenition in Irish changes stops and m into continuants (fricatives or glides), and deletes f; s is debuccalized to h, but only before vowels and coronal sonorants (before m and obstruents s is unaffected by Lenition). The coronals t and d also undergo debuccalization, becoming h and ɣ respectively (see Ní Chiosáin 1991, 27f. for a discussion of why d → ɣ is to be considered debuccalization). In many dialects, the "tense sonorants" L and N become lenited to their "lax" counterparts l and n.[1] Vowels are not affected by Lenition, nor, in most dialects, is r.[2] Eclipsis changes voiceless stops and f into their voiced counterparts, changes voiced stops into the corresponding nasals, and attaches n to vowel-initial words. Sonorant consonants are not affected by Eclipsis, nor is s in most dialects.[3] In the orthography, Lenition of obstruents and m is indicated by placing an ⟨h⟩ after the first letter; Lenition of l and n is not shown. Eclipsis is shown orthographically by placing the letter of the mutated consonant before that of the radical (unmutated) consonant.

(1) *Irish* (Cʹ stands for a phonemically palatalized C)
[phonemic transcription], ⟨orthographic representation⟩

Radical form	Lenition	Eclipsis
[p, pʹ] ⟨p⟩	[f, fʹ] ⟨ph⟩	[b, bʹ] ⟨bp⟩
[t, tʹ] ⟨t⟩	[h, h ~ xʹ] ⟨th⟩	[d, dʹ] ⟨dt⟩
[k, kʹ] ⟨c⟩	[x, xʹ] ⟨ch⟩	[g, gʹ] ⟨gc⟩
[b, bʹ] ⟨b⟩	[w ~ v, vʹ] ⟨bh⟩	[m, mʹ] ⟨mb⟩
[d, dʹ] ⟨d⟩	[ɣ, ɣʹ ~ j] ⟨dh⟩	[N, Nʹ] ⟨nd⟩
[g, gʹ] ⟨g⟩	[ɣ, ɣʹ ~ j] ⟨gh⟩	[ŋ, ŋʹ] ⟨ng⟩
[f, fʹ] ⟨f⟩	∅ ⟨fh⟩	[w~v, vʹ] ⟨bhf⟩
[s, sʹ] ⟨s⟩	[h, h ~ xʹ] ⟨sh⟩	*no change*
[m, mʹ] ⟨m⟩	[w ~ v, vʹ] ⟨mh⟩	*no change*
[N, Nʹ] ⟨n⟩	[n, nʹ] ⟨n⟩	*no change*
[L, Lʹ] ⟨l⟩	[l, lʹ] ⟨l⟩	*no change*
[r] ⟨r⟩	*no change*	*no change*
vowel	*no change*	[N] or [Nʹ] ⟨n-⟩ + vowel

As shown in (2), Welsh has three mutations: Soft Mutation (also called Lenition; abbreviated SM), Nasal Mutation (NM), and Aspirate Mutation (more accurately called Spirantization; abbreviated AM). SM voices voiceless stops and liquids, spirantizes b, d, m, and deletes g. SM does not affect voiceless fricatives, n, or j. NM converts voiceless stops into voiceless nasals and voiced stops into plain nasals; it does not affect other sounds. AM converts voiceless stops into fricatives and does not affect other sounds.

1 The Lenition of l and n sounds is described for the dialects of Aran (Finck 1899), Erris (Mhac an Fhailigh 1968), and Cois Fhairrge (de Bhaldraithe 1945/1975, 1953/1977) in the west and of Meenawannia (Quiggin 1906), The Rosses (Ó Searcaigh 1925), South Armagh (Sommerfelt 1929), Torr (Sommerfelt 1965), and Tangaveane/Commeen (Hughes 1986) in the north. Many fieldworkers in the first half of the twentieth century found a contrast between lenited and unlenited l and n sounds only among older speakers; it may be nearly extinct today.

2 Ó Siadhail (1989: 112) reports that some speakers from the south use palatalized rʹ as the lenited correspondent of r.

3 There are dialects of Irish where z is found as the Eclipsis correspondent of s (Ó Siadhail 1989: 114).

(2) *Welsh*

Radical	SM	NM	AM
[p] ⟨p⟩	[b] ⟨b⟩	[m̥] ⟨mh⟩	[f] ⟨ph⟩
[t] ⟨t⟩	[d] ⟨d⟩	[n̥] ⟨nh⟩	[θ] ⟨th⟩
[k] ⟨c⟩	[g] ⟨g⟩	[ŋ̊] ⟨ngh⟩	[x] ⟨ch⟩
[b] ⟨b⟩	[v] ⟨f⟩	[m] ⟨m⟩	*no change*
[d] ⟨d⟩	[ð] ⟨dd⟩	[n] ⟨n⟩	*no change*
[g] ⟨g⟩	∅ ⟨⟩	[ŋ] ⟨ng⟩	*no change*
[f] ⟨ff⟩	*no change*	*no change*	*no change*
[s] ⟨s⟩	*no change*	*no change*	*no change*
[x] ⟨ch⟩	*no change*	*no change*	*no change*
[h] ⟨h⟩	*no change*	*no change*	*no change*
[m] ⟨m⟩	[v] ⟨f⟩	*no change*	*no change*
[n] ⟨n⟩	*no change*	*no change*	*no change*
[ɬ] ⟨ll⟩	[l] ⟨l⟩	*no change*	*no change*
[r̥] ⟨rh⟩	[r] ⟨r⟩	*no change*	*no change*
[j] ⟨i⟩	*no change*	*no change*	*no change*

Consonant mutations are found in the other Insular Celtic languages as well: Scots Gaelic, Breton, Cornish, and Manx (discussed below).

1.2 The environments of the mutations

The environments in which the various mutations are found are not phonological but morphosyntactic. Most cases of mutation are found on a lexical word either when this is preceded by a function word (proclitic-triggered mutation) or when it occurs in a specific syntactic environment (syntax-triggered mutation). The environments for the mutations are extremely varied, arbitrary, and unpredictable, and are often subject to dialectal variation.

For example, in both Irish and Welsh, nouns are sometimes mutated after the definite article.[4] In Welsh (3), SM is found only when the noun is feminine singular (except that ɬ and r̥ are not mutated here); in other cases the radical form is used. For reference, the radical form is listed on the right.

(3) Mutations of nouns after the definite article in Welsh

Masc. sing.	Radical	y **b**ardd	'the poet'	
Fem. sing.	SM	y **f**aner	'the flag'	(baner)
Plural	Radical	y **b**eirdd	'the poets'	
		y **b**aneri	'the flags'	

In Irish the situation is more complicated, partly because Irish nouns are inflected for case. In the singular, masculine nouns after the definite article are not mutated in the nominative, but undergo Lenition in the genitive. With feminine nouns it is exactly reversed: they undergo Lenition in the nominative after the definite article, but take the radical form in the genitive. Singular nouns of both genders undergo Lenition in the dative after the definite article when governed by one of the prepositions *de* 'from', *do* 'to', or *i* 'in', and either Lenition or Eclipsis

4 In what follows, most Irish examples are from Christian Brothers (1960), Ó Dónaill (1977), or the Tobar na Gaedhilge database (Ó Duibhín 2003). Most Welsh examples are from King (1993) or Thorne (1993).

(depending on dialect) when governed by any other preposition taking the dative.[5] In the plural (of both genders) the radical is used in the nominative and dative after the definite article, but there is Eclipsis in the genitive. Examples are shown in (4).

(4) Mutations of nouns after the definite article in Irish

Masc. nom. sing.	Radical	an **f**ear	'the man'	
Masc. gen. sing.	Lenition	an **fh**ir	'of the man'	(fir)
Fem. nom. sing.	Lenition	an **bh**róg	'the shoe'	(bróg)
Fem. gen. sing.	Radical	na **b**róige	'of the shoe'	
Dat. sing.	Lenition after *de* 'from', *do* 'to', *i* 'in'	den **fh**ear	'from the man'	(fear)
		don **bh**róg	'to the shoe'	(bróg)
		sa **ch**rann	'in the tree'	(crann)
	Lenition or Eclipsis (according to dialect) after other prepositions	ag an **fh**ear/ ag an **bhf**ear	'at the man'	(fear)
		faoin **bh**róg/ faoin **mb**róg	'under the shoe'	(bróg)
Nom. plural	Radical	na **f**ir	'the men'	
		na **b**róga	'the shoes'	
Gen. plural	Eclipsis	na **bhf**ear	'of the men'	(fear)
		na **mb**róg	'of the shoes'	(bróg)
Dat. plural	Radical	do na **f**ir	'to the men'	
		faoi na **b**róga	'under the shoes'	

The coronal stops t, d do not undergo Lenition after the definite article: *an **t**í* 'of the house' (masc. gen. sg.), *an **d**eoir* 'the tear' (fem. nom. sg.). The coronal fricative s is lenited after the definite article not to h (as usual), but rather to t (orthographic ⟨ts⟩), as shown in (5).

(5) Lenition of s to t ⟨ts⟩

an **ts**agairt	[ən tagərt]	'of the priest' (masc. gen. sg.)	(sagairt)
an **ts**úil	[ən tu:l]	'the eye' (fem. nom. sg.)	(súil)

Since this is phonologically a fortition, it can be seen that the morphological Lenition mutation is not always manifested by phonological weakening.

Vowel-initial nouns are incapable of undergoing Lenition, but rather mark its absence in the places where consonant-initial nouns take the radical form. In the masculine nominative singular, a vowel-initial noun acquires a prothetic t after the definite article, see (6a), while in the feminine genitive singular and in the plural a vowel-initial noun acquires a prothetic h after the definite article, as in (6a) and (6b).

(6) Vowel-initial nouns in nonleniting contexts after the definite article

a.	an **t**-asal	'the donkey'	(asal)
b.	na **h**eaglaise	'of the church'	(eaglaise)
c.	na **h**éin	'the birds'	(éin)

[5] With a few lexicalized exceptions, a noun in the standard language has the same form in the dative as in the nominative, except for the different mutation effect after the definite article. In Irish, the dative is found only in conjunction with a preposition (but not all prepositions govern the dative).

A complete list of environments where the mutations are found would not only go beyond the bounds of this paper, it would distract from the point, which is simply that the mutations are found in a wide variety of unrelated environments, and no broad generalizations can be made about where which mutation occurs, either in Irish or in Welsh (or indeed in any of the other Celtic languages). The interested reader may refer to the Appendix for lists, with examples, of other environments in which various words undergo mutation in Irish and Welsh.

That the environments of the mutations are nonphonological is not controversial. But in this paper I will argue that the mutation processes are not phonological either, which frees the analysis from the restrictions imposed by phonology and acknowledges that the mutations are arbitrary in occurrence and only partially predictable in form. This point is illustrated in §2, where the nonphonological Lenition mutation is contrasted with a truly phonological lenition process in Manx, a language closely related to Irish. In §3 I discuss further evidence against a phonological analysis and in §4 I propose a morphological analysis assuming a word-based lexicon in which the mutated forms of words are listed as allomorphs. §5 concludes the paper.

2 Manx

2.1 Morphosyntactically triggered Lenition

Manx (Jackson 1955, Broderick 1984–86), a now extinct[6] close relative of Irish, had a single initial consonant mutation, namely Lenition, which was however only sporadically used in the spoken language, and mostly only in fixed expressions. The original effects (as attested primarily in Literary Manx) of this morphosyntactically triggered Lenition (abbreviated ML) are comparable to those of Irish illustrated above in (1); the effects in Manx are shown in (7).

(7) Effects of ML in Manx

Radical	Lenition
p	f
t, t□	h ~ x, h ~ x□
k, k□	h ~ x, h ~ x□
b	w ~ v
d, d□	ɣ, j
g, g□	ɣ, j
f	∅
s, s□	h, h ~ x□
m	w ~ v
n, n□	*no change*
l, l□	*no change*
r	*no change*
vowel	*no change*

The environments where ML is found in Manx are also largely comparable to the environments where Lenition is found in Irish, although in the late spoken language Lenition was probably absent more often than present in most of these environments.

[6] The last native speaker of Manx died in 1974; the last semi-native speaker in 1985.

(8) Some environments of ML in Manx

feminine singular nouns after the definite article		
ən vedn	'the woman'	(bedn)
nouns after certain (not all) possessive pronouns		
mə xre:wən	'my bones'	(kre:wən)
nouns after certain numerals		
de: fe:t□s□ə	'two children'	(pe:t□s□ə)
nouns after certain prepositions		
də ɣulis□	'to Douglas'	(dulis□)
dative singular nouns after article		
sə xa:rt	'in the cart'	(ka:rt)
adjectives after feminine singular nouns		
iris□vai	'good weather'	(mai)
verbs in the past tense		
vris□	'broke'	(bris□)

An OT analysis assuming that ML is part of the phonology of Manx would have to show that there are circumstances under which the unfaithful correspondence relationships /b/ [v][7], /k/ [x], /p/ [f], /d/ [ɣ], /m/ [v], etc., are more harmonic than the faithful relationships /b/ [b], etc., as well as other possible unfaithful relationships including /d/ [ð] and /t/ [θ]. In principle, such an analysis could certainly be made to work, but, as we shall see in the next section, it will be difficult to maintain in the light of the phonologically triggered (specifically, intervocalic) lenition also found in Manx.

2.2 Phonological lenition

The phonology of late spoken Manx included a variable process of intervocalic lenition of obstruents.[8] Voiceless obstruents were voiced and stops (whether originally voiced or voiceless) were spirantized; underlyingly voiceless stops could undergo both changes. The effects of this process, which I will call Phonological Lenition or PL, are shown in (9) and examples are shown in (10). Crucially, the effects of PL are different from the effects of ML, with the exception of the voiced stops. While under ML voiceless stops remain voiceless but must become fricatives, under PL voiceless stops must become voiced but may remain stops. Also the fricatives s, x become voiced under PL, while under ML s debuccalizes to h and x is not affected.

(9) Effects of Phonological Lenition (PL) in Manx (domain: word-internal V_V; optional)

p > b ~ v	b > v	
t > d ~ ð	d > ð	s > ð ~ z
k > g ~ ɣ	g > ɣ	x > ɣ ~ h ~ ∅

7 The notation /□/ [□] stands for "the input □ stands in a correspondence relationship with the output □." See McCarthy & Prince (1999) for the nature of correspondence relationships.

8 There are some examples of b and d being spirantized in word-initial position as well.

(10) Examples of intervocalic PL

tapi ~ tabi ~ tavi	'quick'
bratag ~ bradag ~ braðag	'flag'
fi:kəl ~ fi:gəl ~ fi:ɣəl	'tooth'
t□bərt ~ t□vərt	'a well'
edən ~ eðən	'face'
rugət ~ ruɣət	'born'
pre:sən ~ pre:zən ~ pre:ðən	'potatoes'
le:xən ~ le:ɣən ~ le:hən ~ le:ən	'days'

The first problem encountered in an analysis of PL is the variability of the process. Boersma (1998) has argued that free variation is analyzable in terms of stochastic constraint ranking, where each constraint has a range along a spectrum in which it applies. If two constraints are close to each other, their ranges may overlap, resulting in variable ranking between them: when constraint A and constraint B overlap, sometimes the ranking will be A ≫ B and sometimes it will be B ≫ A. A full analysis of PL would have to take the variation into consideration, but the point of this paper is not to analyze PL but rather to show that only PL but not ML is part of the phonology of Manx. Therefore, for the sake of simplicity I will assume a variety of Manx where only the voiced fricative outputs are optimal.

Assuming that voiceless stops in the input correspond to voiced fricatives in the output when in intervocalic position, the constraints necessary to an analysis are the faithfulness constraints on voicing IDENT(voi), on continuity IDENT(cont), and on place IDENT(lab), IDENT(cor), IDENT(dor), as well as the markedness constraints *V[□voi]V (no voiceless sound between two vowels) and *V[□cont]V (no noncontinuant sound between two vowels). As shown in (11) – (13), the faithfulness constraints for place are high ranking, as are the two markedness constraints. The faithfulness constraints for voicing and continuity are ranked low.

(11)

/tapi/	IDENT(lab)	*V[□voi]V	*V[□cont]V	IDENT(voi)	IDENT(cont)
tapi		* !	*		
tabi			*!	*	
☞ tavi				*	*
tafi		* !			*
tahi	* !	*			*

Since coronals are not debuccalized under PL, as they are under ML, the high rank of IDENT(cor) in Manx phonology is established, as shown in (12) – (13).

(12) t → ð not h in PL (cf. t → h in ML)

/bratag/	IDENT(cor)	*V[−voi]V	*V[−cont]V	IDENT(voi)	IDENT (cont)	*ð
bratag		* !	*			
bradag			* !	*		
☞braðag				*	*	*
brahag	* !	*			*	

(13) d → ð not ɣ in PL (cf. d → ɣ in ML)

/edən/	IDENT(cor)	*V[−cont]V	IDENT(cont)	*ð
edən		* !		
☞eðən			*	*
eɣən	* !		*	

In the case of s, the constraint *V[−cont]V is irrelevant since it is not violated by the candidate that is completely faithful to the input. The result is that no plausible candidate will violate it either, so that IDENT(cont) becomes irrelevant as well. What is interesting in this case is the apparent free variation between ð and z in the output. As mentioned above, a convenient method of analyzing free variation in OT is through stochastic constraint ranking. In the case at hand, we may say that a markedness constraint banning ð and one banning z from appearing in the output are found so close to each other on the ranking continuum that they overlap; sometimes *ð outranks *z, and sometimes *z outranks *ð. The ranking of these two with respect to the other constraints cannot be determined; in (14) I have placed them at the bottom of the hierarchy for convenience, but in fact they could be placed at the top or in the middle without affecting the analysis. I have separated them with a wavy line to indicate that they overlap in the ranking. The other crucial constraints are IDENT(cor), preventing debuccalization or any other change in place of articulation, *V[−voi]V, prohibiting the most faithful candidate [pre:sən] from surfacing, and IDENT(voi), which both optimal candidates violate equally and which therefore cannot decide between them. Once again, the absence of debuccalization is crucial, as it shows the high rank of IDENT(cor) in Manx phonology.

(14) s → z or ð not h in PL (cf. s → h in ML)

/pre:sən/	IDENT(cor)	*V[−voi]V	IDENT(voi)	*ð	*z
pre:sən		* !			
(☞) pre:zən			*		*(!)
(☞) pre:ðən			*	*(!)	
pre:hən	* !	*			

The process of PL in Manx is clearly and uncontroversially phonological. Both of its effects, voicing and spirantization in intervocalic position, are crosslinguistically well attested, and above all, the process affects natural classes in a uniform way. The same cannot be said for ML.

2.3 An attempt at a phonological analysis of ML

A derivational analysis of ML could follow the analyses of Ní Chiosáin (1991) and Grijzenhout (1995) for Irish and of Ball & Müller (1992) and Pyatt (1997) for Welsh in proposing a set of rules effecting the changes seen in (7). Since derivational rules are allowed to be arbitrary and to be free from phonetic grounding or universal markedness considerations, nothing specific need be said about the triggers for such rules. But in an OT analysis one would have to posit something specific in the input that triggers the mutation; the output with the mutation must be shown to be more harmonic than an alternate candidate with the radical form. The most obvious choice for that something specific in the input is a floating autosegment, as proposed by Lieber (1987). Kibre (1995) does just this as a first approximation, but ultimately argues that the analysis is insufficient and that a combination of rules and OT constraints is necessary to analyze the mutations of Welsh. Gnandesikan (1997), whose focus is not on the triggers of the mutations but rather on the representation of the phonology of Irish mutations, also assumes a morpheme consisting of a floating scale value (taking the place of traditional privative or binary features) as the trigger of that mutation. Translating these accounts into an analysis of ML in Manx, one might assume an underspecified morpheme L that contains at least the feature [+cont] (or maybe some sort of scale value as Gnanadesikan argues for Irish); this morpheme appears in ML environments and coalesces with the initial consonant of the stem to cause the changes shown in (7).

The constraint MORPHREAL requires the distinct realization of a morpheme; it makes the following requirements (Gnanadesikan 1997, 57):

(15) MORPHREAL

A morpheme must be realized by fulfilling one of the following conditions:

a. the output affixed form contains at least one segment not in the unaffixed form, and that segment(s) is coindexed with a segment(s) in the affix's input;
b. the output affixed form contains a segment which is coindexed with the affix's input and that segment has a scale (or feature) value contained in the affix's input but not in the unaffixed form;
c. the output affixed form contains a segment which is coindexed with the affix's input and that segment has a scale value adjacent to that of the affix's input. That value does not occur in the unaffixed form.

MORPHREAL is violated by the first candidate in (16) because the morpheme /L/ is not present in the output in a way that is distinct from the radical form of [bedn]. The winning candidate coalesces /L/ and /bedn/ into [vedn].

(16)

/ən L bedn/	MORPHREAL	IDENT(cont)
ən bedn	* !	
☞ ən vedn		*

Alternatively, the trigger might be not an independent morpheme /L/ but instead a floating autosegment at the right edge of the definite article, whose input would then be not /ən/ but /ənL/. In this case, L would be almost like a segment, except that it has no root node and consists only of the features necessary to trigger ML (either [+cont], or under Gnanadesikan's theory, a scale value). The constraint ruling out *[ən bedn] would then be not MORPHREAL but rather MAX(L).

(17)

/ənL bedn/	MAX(L)	IDENT(cont)
ən bedn	* !	
☞ ən vedn		*

There are a number of arguments against both of these analyses. In §3 I discuss some of the arguments against such an analysis for Celtic mutations in general; one argument that is specific to Manx is the fact that we are confronted with a ranking paradox. Above in (13) we saw that IDENT(cor) crucially outranks *ð in PL, but since d becomes ɣ under ML, the opposite ranking must hold here, as shown in (18).

(18)

/də L_1 $d_2$ulis□/	MORPHREAL	*ð	IDENT(cor)	IDENT(cont)
də $d_{1,2}$ulis□	* !			
də $ð_{1,2}$ulis□		* !		*
☞ də $ɣ_{1,2}$ulis□			*	*

Because the PL facts show that Manx does tolerate ð in the output, there is no good reason why a process that changes noncoronal stops into the corresponding fricatives should remove the coronality of d. As for t, we do not expect them to have the same output under ML (which respects input voicing specifications) as under PL (whose outputs are always voiced), but nevertheless debuccalization of t to h appears phonologically unmotivated. According to Broderick (1984–86, 3: 5), Manx has surface θ as an optional allophone of /t/ after /s/ in word-medial position, e.g. [sa:stən ~ sa:sθən] 'England', [fa:sti ~ fa:sθi] 'shelter', implying that there is no blanket prohibition on output θ in Manx. Why then should θ not be the ML correspondent of t? Arguments that ML (but not PL) must be "structure-preserving" (i.e. that it cannot produce sounds that are outside the phonemic inventory of Manx) fail because ML does produce ɣ, which is not a phoneme of Manx.

Unlike the other Celtic languages, Manx has a phonological lenition whose effects, as we have seen in this section, have serious repercussions on any phonological analysis of ML. A ranking paradox arises if we try to generate both PL and ML from the same constraint ranking. Only PL is clearly an interaction of markedness and faithfulness. An OT-phonological analysis of ML must allow faithfulness to be violated without an improvement in markedness, a situation that is not supposed to occur if the strongest version of the OT phonology hypothesis is correct. As we see in the next section, there are equally strong reasons from other Celtic languages to believe that the mutations are not phonological processes.

3 Why the mutations cannot be phonological at all

Not only are the environments of the mutations nonphonological, the mutation processes themselves cannot convincingly be analyzed as phonological either. First of all, there is no feature or bundle of features that can effect the wide variety of alternations found within a single mutation. Secondly, in the case of mutations triggered by syntactic position, a phonological account depends on the assumption of a segmentally empty morpheme containing the mutation-triggering features, but in such cases there is almost never independent evidence for the existence of such a morpheme. Rather, morphemes must be posited for no other reason than to "explain" the occurrence of a mutation. Thirdly, mutations are sometimes triggered by proclitics that are not adjacent to the word undergoing mutation. Finally, mutations are subject to a variety of lexical exceptions and irregularities that are inconsistent with a phonological analysis.

3.1 Features triggering mutations

The first major problem a phonological account of the mutations encounters is the wide variety of changes triggered. Irish Lenition, for example, turns oral stops and m (but not n) into fricatives, debuccalizes coronal obstruents, "laxes" tense coronal sonorants, and deletes f. What feature(s) could cause these changes? [+continuant] alone will trigger only the spirantization, not the debuccalization, sonorant laxing[9], or f-deletion. [□coronal] could conceivably account for the debuccalization of coronals, but the majority of researchers on distinctive features (Sagey 1986, McCarthy 1988, Hume 1992, Clements & Hume 1995) agree that [coronal] is actually a privative feature with no minus value. If a case can be made that what distinguishes [L, L□, N, N□][10] from [l, l□, n, n□] is the feature [tense] (as assumed, for example, by Ó Siadhail 1989: 92 ff.), then [□tense] could account for the sonorant laxing, but not the other cases. And it is difficult to conceive of any feature that could be added to f to induce deletion. Unlike truly phonological processes (PL in Manx, for example), the mutations do not target natural classes of sounds or have uniform effects. Neither do they improve markedness, as the strong OT phonology hypothesis predicts phonological processes should when faithfulness is violated.

In the next sections we will examine the various environments of the mutations and show that the predominant assumption about their triggers, namely that floating autosegments coalesce with initial consonants to cause the mutations, cannot be supported. In most cases there is no independent evidence for the existence of the morphemes these floating autosegments are supposed to represent. Furthermore, there are so many irregularities and exceptions to mutations, both on the part of the triggers and on the part of the targets, that an analysis operating within the strict bounds of phonological theory simply falls apart.

3.2 Syntactically triggered mutations

Analyses that assume a segmentally empty morpheme to trigger mutations are plagued by the inability to provide independent evidence for the morpheme proposed. This is most noticeably the case in mutations that are triggered by syntactic position rather than by an overt proclitic. As shown in (19), attributive adjectives in Irish are lenited when they modify a feminine singular noun, as in (19a). Adjectives are not lenited, however, when they modify a masculine singular noun, as in (19b). When adjectives modify a plural noun they are lenited only if the noun ends in a palatalized consonant; if more than one adjective is present only the first is lenited, see (19c). If the plural noun does not end in a palatalized consonant the adjective is not lenited, see (19d).

(19) Irish Lenition of attributive adjectives

a.	bean	**mh**ór	**dh**ubh	(mór, dubh)
	woman	big	dark	
	'a big dark woman'			

[9] Lenited [l, l□, n, n□] are still [□continuant], showing that [+continuant] cannot be argued to be a consistent feature of Lenition.

[10] In narrow phonetic transcription, [ɫ̪ː, ʎː, n̪ˠː, ɲː].

b. fear **m**ór **d**ubh
man big dark
'a big dark man'

c. fir **mh**óra **d**ubha (fir = [f□ir□]) (móra)
men big-PL dark-PL
'big dark men'

d. mná **m**óra **d**ubha
women big-PL dark-PL
'big dark women'

It is virtually impossible to conceive of a functional element that could be found in the Lenition environments of (19): what morpheme could be found in these syntactic positions? Even if an argument could be made for the existence of such an element, there is no independent evidence for it: the only evidence for the presence of a morpheme is the Lenition the morpheme has been invented to explain, and the analysis is nothing more than begging the question.

The exact same point can be made for the syntactically triggered Lenition in (20). Definite noun phrases in a genitival function undergo Lenition, regardless of whether they are morphologically in the genitive case ((20a)) or not ((20b)).

(20) Irish Lenition of genitival definite noun phrases

a. muintir **Sh**eáin (Seáin)
family S.-GEN
'Seán's family'

b. mac [**fh**ear an tí] (fear)
son man the house-GEN
'the son of the man of the house; the landlord's son'

Once again, even if we were to argue that there is, for example, a segmentless preposition meaning 'of' in these phrases, there is no independent evidence for it, and we have merely invented an ad-hoc construct that explains nothing.

One of the most contentious mutations among Celtic syntacticians is the Welsh SM commonly called "direct object mutation" illustrated in (21). As shown in (21a), the direct object of a finite verb undergoes SM, while as shown in (21b), there is no SM when the verb is nonfinite (e.g. the verbal noun, abbreviated VN). (Examples from the handout of Tallerman 2003.)

(21) Welsh direct object mutation

a. Prynodd y ddynes **f**eic. (beic)
bought the woman bike
'The woman bought a bike.'

b. Roedd y ddynes yn prynu **b**eic.
was the woman PROG buy-VN bike
'The woman was buying a bike.'

There are two major schools of thought on this problem. Some researchers (e.g. Zwicky 1984, Roberts 1997) have argued that the SM in (21a) is a manifestation of accusative Case (which is otherwise not morphologically indicated in Welsh, not even on pronouns as in English), the idea being that the object of a nonfinite verb is not in the accusative. Roberts (in press) argues that the trigger is a floating-autosegment morpheme located in *v* (a functional head preceding VP, in the Spec position of which the direct object is found).

Other researchers (e.g. Borsley & Tallerman 1996, Tallerman 1998, 1999, 2003, Borsley 1997, 1999) have pointed out a number of problems with the Case-based analysis and have argued that the SM is triggered instead by a preceding c-commanding phrase or phrasal sister. This suggestion is known as the XP Trigger Hypothesis (XPTH). The evidence for the XPTH comes from the following facts: the direct object of a nonfinite verb *is* lenited when it is separated from the verb by another phrase like a prepositional phrase or adverbial phrase. Compare the absence of SM in (21b) with its presence in (22).

(22) Direct object of verbal noun lenited after PP or AdvP

Yr oedd Prŷs yn rhagweld [$_{PP}$ yn 1721] **d**ranc yr iaith Gymraeg.
was P. PROG foresee-VN in death the Welsh language
'Prŷs foresaw in 1721 the death of the Welsh language.' (tranc)

yn ffaelio [$_{AdvP}$ 'n glir lân] **dd**yscu 'r gelfyddyd (dyscu)
PROG fail-VN PRED complete learn-VN the art
'completely failing to learn the art'

There are also cases where a noun or verbal noun that cannot be in the accusative is lenited after a phrase in a marked word order, as shown in (23).

(23) SM after a phrase in a marked word order

Mae [$_{PP}$ yn yr ardd] **g**i. (ci)
is in the garden dog
'There's a dog in the garden.'

Mae chwant [$_{PP}$ arnaf i] **f**ynd adre'. (mynd)
is desire on me go-VN home
'I want to go home.'

Erfyniodd [$_{PP}$ arnaf i] **f**ynd gydag ef. (mynd)
begged-3SG on me go-VN with him
'He begged me to go with him.'

The nonfinite verb of an embedded complement clause is lenited after its subject, as shown in (24).

(24) SM of a nonfinite verb after its subject

Mae Aled yn awyddus i Rhys **f**ynd adre'. (mynd)
is A. PRED eager to R. go-VN home
'Aled is eager for Rhys to go home.'

Wrth i Aled **dd**od allan, mi aeth Mair i mewn. (dod)
as to A. come-VN out PRT went-3SG M. in
'As Aled came out, Mair went in.'

The subject of a sentence lenites whatever follows it, as shown in (25). This instance also subsumes the SM in (21a). Note in (25b) and (25d) that even the negative particle *dim* can be lenited, proving that not only nouns are subject to this syntactically triggered SM.

(25) SM after the subject

a.	Gall	y dyn	**dd**reifio	'r car.		(dreifio)
	can	the man	drive-VN	the car		
	'The man can drive the car.'					
b.	All	y dyn	**dd**im	dreifio	'r car.	(dim)
	NEG-can	the man	NEG	drive-VN	the car	
	'The man can't drive the car.'					
c.	Gwnaeth	Aled	**w**eld	y ffilm.		(gweld)
	did-3SG	A.	see-VN	the film		
	'Aled saw the film.'					
d.	Gwnaeth	Aled	**dd**im	gweld	y ffilm.	(dim)
	did-3SG	A.	NEG	see-VN	the film.	
	'Aled didn't see the film.'					

The conclusion that Tallerman and Borsley come to is that SM is triggered simply by the presence of a preceding XP, not by a functional morpheme like *v*. This conclusion supports the contention of the current paper that mutations are not triggered by silent morphemes consisting solely of floating features.

3.3 Nonadjacency

There are a number of cases of mutation triggered by a proclitic that is not adjacent to the word undergoing the mutation. For example In Irish, when a noun is governed both by a possessive pronoun and by *dhá* 'two', it is the pronoun that determines the mutation. Without a possessive pronoun before, *dhá* always causes Lenition. In (26a) – (26c), both the pronoun and the numeral independently cause Lenition, so we cannot tell which is triggering Lenition when both occur together. But in (26d) we see that the pronoun triggers the radical form, even when the numeral intervenes. If *dhá* were to end in a floating Lenition-triggering autosegment, we have no explanation for why Lenition is blocked here. It is the pronoun that determines the mutation or nonmutation of the noun, even when the pronoun is not adjacent to the noun. This is made even more clear in (26e) – (26g), where the pronoun triggers Eclipsis and the numeral Lenition. Once again, it is the nonadjacent pronoun rather than the adjacent numeral that determines the mutation of the noun.

(26) Possessive pronoun + *dhá* + noun (Irish)

a.	mo **mh**ala	'my eyebrow'	(mala)
	dhá **mh**ala	'two eyebrows'	
	mo dhá **mh**ala	'my two eyebrows'	
b.	do **ch**éaslaidh	'your (sg.) paddle'	(céaslaidh)
	dhá **ch**éaslaidh	'two paddles'	
	do dhá **ch**éaslaidh	'your (sg.) two paddles'	
c.	a **gh**lúin	'his knee'	(glúin)
	dhá **gh**lúin	'two knees'	
	a dhá **gh**lúin	'his two knees'	
d.	a **s**úil	'her eye'	(súil)
	dhá **sh**úil	'two eyes'	
	a dhá **s**úil	'her two eyes'	

e.	ár **gc**uid	'our part'	(cuid)
	dhá **ch**uid	'two parts'	
	ár dhá **gc**uid	'our two parts'	
f.	bhur **dt**each	'your (pl.) house'	(teach)
	dhá **th**each	'two houses'	
	bhur dhá **dt**each	'your (pl.) two houses'	
g.	a **gc**loigeann	'their skull'	(cloigeann)
	dhá **ch**loigeann	'two skulls'	
	a dhá **gc**loigeann	'their two skulls'	

Nonadjacency effects are seen also where a preposition governs two nouns conjoined by *agus* 'and'. The conjunction itself does not trigger Lenition, as shown by the phrase *sioc agus sneachta* (****sh**neachta*) 'frost and snow', but when a leniting preposition like *trí* 'through' governs this phrase, both nouns are lenited: *trí* ***sh**ioc agus* ***sh**neachta* (**sneachta*) 'through frost and snow'. If Lenition were triggered by a floating autosegment at the right edge of the word *trí*, we would expect only the first noun to be mutated, but not the second noun as well. Nonadjacency is found also in cases where an English expletive like *fuckin'* is placed between a possessive pronoun and a noun. In this case, the mutation triggered by the pronoun skips over the expletive and affects the noun, e.g. *Cá bhfuil mo fuckin'* ***sh**eaicéad?* 'Where's my fuckin' jacket?' (Stenson 1990: 171). Again, if Lenition were triggered by a floating autosegment at the right edge of *mo*, we would not expect Lenition of *seaicéad*. (In English words, f resists Lenition, so we do not expect **mo fhuckin' seaicéad*.)

3.4 Irregular behavior of triggers and targets

Finally, the large number of lexical exceptions and irregularities in mutation makes a phonological anaylsis implausible. These may be divided into two major classes: those where the mutation-triggering proclitic exhibits irregular behavior, and those where the target of mutation exhibits irregular behavior. There are examples of both kinds from both Irish and Welsh.

Irregular triggers in Irish. The first example of irregular behavior in mutation triggers comes from Irish numbers. In Irish, a noun after a number is usually in the singular form. The numbers three through six cause Lenition of the noun, as shown in (27).

(27) Lenition of singular nouns after numbers 3–6

3	trí **ch**oiscéim	'three footsteps'	(coiscéim)
4	ceithre **gh**rád	'four degrees'	(grád)
5	cúig **ch**umhacht	'five powers'	(cumhacht)
6	sé **mh**í	'six months'	(mí)

However, certain nouns, mostly indicating measurements, regularly appear in the plural after numbers (in many cases there is a special plural form used *only* after numbers). If the noun is in the plural after a number, then there is no Lenition after the numbers three through six.[11]

(28) No Lenition of plural nouns after numbers 3–6

3	trí **b**liana (*bhliana)	'three years'
4	ar do cheithre **b**oinn (*bhoinn)	'on all fours'

[11] The numbers 7–10 trigger Eclipsis regardless of whether the noun is in the singular or the plural.

5	cúig **c**inn (*chinn)	'five ones (things, animals)'
6	sé **s**lata (*shlata)	'six yards'

If mutations are triggered by a floating autosegment at the right edge of the triggering proclitic, we cannot explain why Lenition fails to appear when the noun is in the plural. Alternatively, it could be argued that a silent morpheme appears between numerals and singular nouns but not before plural nouns, but firstly such a morpheme is difficult to motivate on methodological grounds (why should a morpheme be expected in such a position?) and secondly there is no independent evidence for a morpheme, which would be invented solely to explain the mutation.

Another example of irregular trigger behavior comes from past tense verbs. Historical tenses (past, past habitual, and conditional) of regular verbs (and many irregular verbs) in Irish are characterized by Lenition, regardless of whether a proclitic is present or not (cf. (29a)). A systematic exception to this generalization is the past tense of the so-called autonomous verb form (which has an impersonal or passive meaning), where the radical is found, again regardless of whether a proclitic is present or not (cf. (29b)). In the case of the personal forms, there is in fact evidence for a triggering proclitic: vowel-initial verbs are supplied with a preverb *d'* in historical tenses when no other preverb is present (cf. (29c)).[12] Thus a case could be made that there is a preverbal element before historical tense verbs which surfaces as *d'* before vowels and as Lenition on consonants. Since *d'* is absent before vowel-initial past autonomous forms (cf. (29d.i)), the absence of Lenition in (29b.i) is expected: the triggering particle is absent.

(29) Mutation in the past tense in Irish

a. Lenition in personal forms

i. **bh**ris mé (bris)
break-PAST I
'I broke'

ii. níor **bh**ris mé (bris)
NEG-HIST break-PAST I
'I did not break'

b. Radical in autonomous forms

i. **b**riseadh an chathaoir
break-PAST-AUT the chair
'The chair got broken'

ii. níor **b**riseadh an chathaoir
NEG-HIST break-PAST-AUT the chair
'The chair did not get broken'

c. *D'* before vowel-initial personal forms in absence of other preverb

i. **d'** oscail mé
HIST open-PAST I
'I opened'

ii. níor oscail mé
NEG-HIST open-PAST I
'I did not open'

[12] In old-fashioned literary style, and to some extent in older varieties of spoken Munster Irish, the full form *do* is found also before consonant-initial verbs.

d. No *d'* before vowel-initial autonomous forms

i. osclaíodh an doras[13]
open-PAST-AUT the door
'The door was opened'

ii. níor osclaíodh an doras
NEG-HIST open-PAST-AUT the doras
'The door was not opened'

But a problem arises with (29b.ii): the preverb *níor* triggers Lenition by itself, (29a.ii); it is not followed by the *d'* preverb, (29c.ii). If the mutation is to be represented as a floating autosegment at the right edge of *níor*, we predict *níor* to mutate autonomous forms as well, which it does not.

A third example of irregular behavior in a mutation trigger is the negative particle *cha* of the Ulster (northern) dialect of Irish. This particle triggers Eclipsis of t, d, and vowels[14], leaves s in the radical (which may be a vacuous application of Eclipsis), but triggers Lenition of noncoronal lenitable consonants, as shown in (30). This phenomenon is known as "mixed mutation."[15]

(30) Mixed mutation after *cha* in Ulster

cha **dt**ugann	'does/will not give'	(tugann)
cha **nd**éanaim	'I do/will not do'	(déanaim)
cha**n** abróchainn	'I would not say'	(abróchainn)
cha**n** innseochadh sé	'he would not tell'	(innseochadh)
cha**n** ólann tú	'you do/will not drink'	(ólann)
cha **s**ílfinn	'I would not think'	(sílfinn)
cha **bh**íonn	'is not (habitual)/will not be'	(bíonn)
cha **ch**reidim	'I do not believe'	(creidim)
chan **fh**ágaim	'I do/will not leave'	(fágaim)

The Ulster mixed mutation is even more complicated than any of the usual mutations: it voices t, nasalizes d and vowels, spirantizes noncoronal stops, and deletes f, but does not affect s. It is highly improbable that a single feature or bundle of features, or scale value (Gnanadesikan 1997) can do all of that. And even if one could, why should *cha* be the only word where this feature (bundle) or scale value appears?

The Irish preposition *gan* 'without' has a very irregular mutation pattern. In general, it triggers Lenition, as shown in (31a). However, it fails to lenite nouns that are qualified, (31b), or when it functions as the negation in a nonfinite clause, (31c). It does not lenite the coronals t, d, s (which is not surprising since coronals are usually blocked from leniting after other

[13] In informal varieties of Irish, ***h**osclaíodh an doras* may also be heard (M. Ní Chiosáin, p.c.). Recall from (6) that vowel-initial nouns take a prothetic *h* after radical-triggering forms of the definite article. This is true also after other radical-triggering vowel-final proclitics like *chomh* [xo] 'so', *go* 'to, until', *le* 'with', etc. Thus the pattern became established that vowel-initial words take prothetic *h* in environments where consonant-initial words take the radical form.

[14] It is an orthographic convention that the prothetic *n* that vowels acquire under Eclipsis is written at the end of *cha* rather than the beginning of the following word, hence *chan ólann tú* rather than *cha n-ólann tú* for 'you do not drink'.

[15] This is the pattern prescribed by Ó Dónaill (1977: s.v. *cha*), but in texts written in Ulster Irish (searched on the Tobar na Gaedhilge database, Ó Duibhín 2003) the usage is more variable, with Eclipsis found not only on *t* and *d* but sometimes on other eclipsable consonants as well. In some texts, *d* is left in the radical after *cha*.

coronals: see Ní Chiosáin1991), nor does it lenite f (which is surprising as *gan* is the only leniting proclitic that fails to lenite f), except that it does lenite the word *fios* 'knowledge', as shown in (31d). It does not lenite proper names, as shown in (31e), although other leniting prepositions do lenite proper names (e.g. *ó **Mh**ícheál* 'from Mícheál').[16]

(31) Mutation pattern of *gan* 'without'

a. Generally triggers Lenition

gan **ch**iall	'without sense; senseless'	(ciall)
gan **mh**aith	'without good; useless'	(maith)
gan **mh**eabhair	'without consciousness; unconscious'	(meabhair)
gan **bh**réag	'without lie; indisputable'	(bréag)
fear gan **ph**ósadh	'man without marriage; unmarried man'	(pósadh)
cailín gan **mh**úineadh	'girl without manners; unmannerly girl'	(múineadh)
fan gan **ch**orraí	'wait without motion; wait motionless'	(corraí)
fágtha gan **ch**ompánaigh	'left without companions'	(compánaigh)

b. No Lenition when the noun is qualified

gan **b**réag ar bith 'without any lie at all; completely indisputable'
gan **p**ingin ina phóca 'without a penny in his pocket'

c. No Lenition when functioning as negation in a nonfinite clause

B' fhearr duit gan **c**orraí.
COP-COND better for-you without move-VN
'It would be better for you not to move.'

Abair leis gan **p**ósadh.
say with-him without marry-VN
'Tell him not to marry.'

Mol dó gan **p**ingin a chaitheamh.
advise to-him without penny to spend-VN
'Advise him not to spend a penny.'

d. No Lenition of coronals or f (except *fios* 'knowledge')

i.	gan **t**eip	'without fail'	
ii.	gan **d**abht	'without a doubt; doubtless'	
iii.	gan **s**agart	'without a priest'	
iv.	gan **f**reagra	'without an answer'	
v.	gan **fh**ios	'without knowledge, unknowing'	(fios)

e. No Lenition of proper names

Tháinig tú gan **M**ícheál. 'You came without Mícheál.'

The only failure of Lenition in (31) that can be explained phonologically is that of (31d.i–iii), where coronals fail to lenite after the *n* of *gan*. All the other cases where *gan* does not trigger Lenition are unexplainable if we believe that *gan* contains a floating Lenition-triggering autosegment at its right edge.

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[16] This contrasts with Welsh, where proper names generally fail to undergo mutation in *any* environment.

The preposition *ar* 'on' also generally triggers Lenition, as shown in (32a). However, many descriptive PPs using *ar*, generally translatable with English adjectives, have the radical form of the noun after the preposition ((32b)). Unqualified phrases of location using *ar* have the radical form ((32c)), but once these same phrases are qualified, *ar* once again triggers Lenition ((32d)). In complex prepositions (i.e. PPs that function as prepositions, cf. English *for the sake of, in place of*) *ar* does not mutate a following noun (32e)). Finally, there are a few adverbial stock phrases in which *ar* triggers Eclipsis ((32f)). Many of the above-mentioned generalizations have exceptions, some of which are listed in the table.

(32) Mutation pattern of *ar* 'on'

a. Generally lenites

ar **bh**ád	'on a boat'	(bád)
ar **bh**ealach	'in a way'	(bealach)
ar **bh**ord	'on a table'	(bord)
ar **ch**aoi	'in a way'	(caoi)
ar **ch**lé	'on the left'	(clé)
ar **ch**or ar bith	'at all'	(cor 'turn')
ar **ch**untar	'on condition'	(cuntar)
ar **dh**eis	'on the right'	(deis)
ar **dh**óigh	'in a way'	(dóigh)
ar **dh**ul amach	'upon going out'	(dul)
ar **fh**aitíos	'for fear'	(faitíos)
ar **th**eacht abhaile dom	'upon my coming home'	(teacht)

b. Radical in certain descriptive phrases (usually translatable with an adjective)

ar **b**ith	'any'	(bith 'world')
ar **b**ogadh	'loose'	(bogadh 'movement')
ar **b**uile	'furious'	(buile 'madness')
ar **c**ois	'afoot'	(cos 'foot')
ar **c**rochadh	'hanging'	(crochadh 'a hanging')
ar **d**íol	'for sale'	(díol 'a sale')
ar **d**óigh	'wonderful'	(dóigh 'way, manner')
ar **d**oimhne	'deep, in depth'	(doimhne 'depth')
ar **f**ad	'long, in length'	(fad 'length')
ar **f**áil	'available'	(fáil 'a getting')
ar **f**iuchadh	'boiling'	(fiuchadh 'a boiling')
ar **f**ónamh	'excellent'	(fónamh 'benefit')
ar **f**orbhás	'top-heavy'	(forbhás 'top-heaviness')
ar **g**or	'brooding (hen)'	(gor 'heat')
ar **m**aos	'saturated'	(maos 'saturation')
ar **m**eisce	'drunk'	(meisce 'drunkenness')
ar **s**eachrán	'astray'	(seachrán 'a wandering')
ar **s**iúl	'going on, in progress'	(siúl 'walking')
ar **t**iús	'thick, in thickness'	(tiús 'thickness')
ar **t**riomú	'drying'	(triomú 'a drying')
Exceptions:		
ar **fh**eabhas	'excellent'	(feabhas 'excellence')
ar **sh**iúl	'gone, away'	(siúl 'walking')

c. Radical in unqualified phrases of general location

ar **b**arr	'on top'
ar **c**olba	'on the outside'
ar **c**orr	'on edge'
ar **d**eireadh	'at last'
ar **m**uir	'at sea'
ar **t**ír	'on land'
ar **t**osach	'in front'

d. Usually, Lenition when phrases of location are qualified

ar **bh**arr an tí	'on the top of the house; on the top story'	(barr)
ar **ch**olba na leapa	'on the side of the bed'	(colba)
ar **ch**orr an bhoird	'on the edge of the table'	(corr)
ar **dh**eireadh an bháid	'on the end (i.e. stern) of the boat'	(deireadh)
ar **Mh**uir Meann	'on the Irish Sea'	(muir)
ar **th**ír na hÉireann	'on the land of Ireland'	(tír)
ar **th**osach an tslua	'at the head of the crowd'	(tosach)

Exceptions:

ar **b**all beag	'in a little while'	(ball 'a while')
ar **b**éal maidine	'first thing in the morning'	(béal 'opening')
ar **b**ord loinge	'on board ship'	(bord 'board')

e. Radical in complex prepositions

ar **f**eadh	'during'	(feadh 'distance')
ar **f**ud	'throughout'	(fad 'length')
ar **s**on	'for (the sake of)'	(son 'well-being')
ar **t**í	'about to'	(tí 'track')

Exception:

ar **mh**odh	'in the manner of'	(modh)

f. Eclipsis in a few adverbial stock phrases

ar **gc**úl	'backwards'	(cúl 'back')
ar **nd**óigh	'of course'	(dóigh 'certainty')

Similarly, the preposition *thar* 'over' generally lenites the initial sound of the noun that follows it, as shown in (33a). It does not mutate certain indefinite, unqualified nouns with a general, often lexicalized, meaning, as shown in (33b), but once these same phrases are qualified, *thar* once again triggers Lenition, as in (33c).

(33) Mutation after *thar* 'over'

a. Lenition in most cases

Ní fiú thar **ph**ingin é.
'It's not worth more than a penny.' (pingin)

Níor fhan sé thar **bh**liain ann.
'He didn't stay more than a year there.' (bliain)

Ní aithneodh sé cat thar **ch**óiste.
'He couldn't tell a cat from a carriage.' (cóiste)

thar **dh**uine eile
'rather than anyone else' (duine)

Ní raibh thar **ch**úigear acu ann. 'There weren't more than five of them there.'		(cúigear)
thar **Ch**orcaigh 'past Cork'		(Corcaigh)
Níl sé thar **mh**oladh beirte. 'It leaves much to be desired (lit. It's not beyond the judgment of two people).'		(moladh)

b. Radical of indefinite, unqualified nouns

thar **b**arr	'tip-top'	(barr 'top')
thar **b**arr amach	'outright'	
dul thar **b**ráid	'pass by'	(bráid 'neck')
thar **c**eann	'on behalf of; instead of'	(ceann 'head')
thar **c**ionn	'excellent'	(ceann 'head')
thar **c**noc	'over a hill'	
thar **d**roichead	'over a bridge'	
thar **f**óir	'beyond measure'	
thar **s**áile	'overseas'	
thar **s**liabh	'over a mountain'	
thar **t**ír	'over land'	

c. Lenition of qualified nouns

thar **bh**arr an chnoic	'over the top of the hill'	(barr)
thar **ch**eann an dochtúir	'over the doctor's head'	(ceann)
thar **dh**roichead na habhann	'over the bridge of the river'	(droichead)
thar **Sh**liabh an Iolair	'over Mount Eagle[17]'	(sliabh)

The peculiar mutation behavior of *ar* and *thar* is a strong argument against a phonological trigger analysis. If mutations are triggered by floating autosegments at the right edge of the triggering proclitic, we cannot explain why Lenition fails to appear in cases like (32b), (32c), (32e), and (33b). Alternatively, it could be argued that a silent Lenition-triggering morpheme appears between these two prepositions and qualified nouns but not before unqualified nouns, but such a morpheme is particularly difficult to motivate in light of the mutation behavior of *gan*, where the behavior of qualified and unqualified nouns is exactly the opposite, see (31a) and (31b).

Irregular triggers in Welsh. Mixed mutation similar to that seen above in (30) for Ulster Irish is found also in Welsh, namely after the particles *ni* 'not', *na* 'not (relative)', and *oni* 'not (interrogative); if not'. As shown in (34), these particles trigger AM of voiceless stops and SM of voiced stops, voiceless liquids, and m.[18]

(34) Mixed mutation after *ni, na*, and *oni* in Welsh

ni **ph**lesiai	'did not please'	(plesiai)
ni **th**âl	'does not pay'	(tâl)
ni **ch**ymerodd	'did not take'	(cymerodd)
oni **ch**lywodd	'has (he) not heard?'	(clywodd)
ni **f**eiddiai	'did not dare'	(beiddiai)
pam na **dd**ylai	'why shouldn't'	(dylai)

[17] A mountain on the Dingle Peninsula, County Kerry.

[18] In the spoken language, the particle *ni* itself is often omitted but its mutation effects remain. In some dialects, AM is moribund and usually replaced by SM.

y pethau na **w**elir	‘the things that are not seen’	(gwelir)
oni **l**wydda	‘unless (he) succeeds’	(llwydda)
ni **r**aid	‘there is no need’	(rhaid)
na **f**eddylier	‘do not think’	(meddylier)

Since this mixed mutation turns all stops[19] into fricatives (unlike regular SM which turns only voiced stops into fricatives) it might be tempting to assume here that *ni, na* and *oni* carry a floating [+cont] feature at their right edge, different from the usual trigger of SM. But this analysis still does not capture the voicing of ɬ and r̥ to l and r, nor is it particularly satisfying in light of the fact that *ni, na,* and *oni* are the only particles that behave this way.

There are a number of environments in Welsh where obstruents and m are lenited, but ɬ and r̥ remain in the radical. These environments include: feminine nouns after the definite article and after *un* ‘one’ see (35a), adjectives after *cyn* ‘as’, *mor* ‘so’, and *pur* ‘quite’, see (35b), and nouns and adjectives after the predicative particle *yn*, see (35c).

(35) SM of consonants except ɬ, r̥ in Welsh

a. Feminine nouns after the definite article and after *un* ‘one’

y **g**yllell	‘the knife’	(cyllell)
y **f**am	‘the mother’	(mam)
y **ll**ysywen	‘the eel’	
y **rh**aff	‘the rope’	
un **f**erch	‘one girl’	(merch)
un **g**ath	‘one cat’	(cath)
un **ll**aw	‘one hand’	
un **rh**wyd	‘one net’	

b. Adjectives after *cyn* ‘as’, *mor* ‘so’ and *pur* ‘quite’

cyn **w**ynned â	‘as white as’	(gwynned)
cyn **g**ryfed â	‘as strong as’	(cryfed)
cyn **ll**awned â	‘as full as’	
cyn **rh**wydded â	‘as easy as’	
mor **d**eg	‘so fair’	(teg)
mor **o**sgeiddig	‘so graceful’	(gosgeiddig)
mor **ll**ydan	‘so broad’	
mor **rh**wydd	‘so easy’	
pur **dd**ieithr	‘quite strange’	(dieithr)
pur **ll**wyddiannus	‘quite successful’	
pur **rh**ydlyd	‘quite rusty’	

c. Adjectives and nouns after the predicative particle *yn*

yn **dd**yn	‘a man’ (pred.)	(dyn)
yn **w**ag	‘empty’ (pred.)	(gwag)
yn **rh**aid	‘necessary’ (pred.)	
yn **ll**ygaid	‘eyes’ (pred.)	

The failure to lenite in (35a) cannot be attributed to any underlying phonological property of the definite article and *un* ‘one’ (such as a specific feature or feature bundle that fails to lenite

19 Except g, which is deleted as usual under SM in Welsh.

ɬ and r̥), because the voiceless liquids are in fact lenited in feminine *adjectives* after these determiners. Examples are shown in (36).

(36) SM of ɬ and r̥ in feminine adjectives after the definite article and *un*

y **l**wyd wawr	'the gray dawn'	(llwyd)
y **l**onnaf	'the happiest (woman)'	(llonnaf)
un **r**yfedd yw hi	'she is a strange one'	(rhyfedd)

As for (35b) – (35c), although there is no direct evidence like (36) showing that the failure to lenite ɬ and r̥ cannot be attributed to the phonology of the triggering proclitic, it seems a priori unlikely since that explanation cannot be right for (35a).

Another case of lexeme-specific mutation is found with the Welsh words *blwydd* 'years old', *blynedd* 'years', and *diwrnod* 'days'. These words undergo NM (optionally in the case of *diwrnod*) after the numbers *pum* '5', *saith* '7', *wyth* '8', *naw* '9', *deng* '10', *pymtheng* '15', *ugain* '20', and *can* '100'. Some examples are shown in (37a). However, these are the only words mutated after these numbers. As shown in (37b), other words use the radical form in this context.

(37) Mutation of *blwydd, blynedd*, and *diwrnod* after certain numbers

a.	5	pum **m**lwydd	'five years old'	(blwydd)
	7	saith **m**lynedd	'seven years'	(blynedd)
	8	wyth **n**iwrnod/**d**iwrnod	'eight days'	(diwrnod)
	9	naw **m**lwydd	'nine years old'	(blwydd)
	10	deng **m**lynedd	'ten years'	(blynedd)
b.	5	pum **d**yn	'five men'	
	7	saith **c**ath	'five cats'	
	8	wyth **b**laidd	'eight wolves'	
	9	naw **b**achgen	'nine boys'	
	10	deng **m**erch	'ten girls'	

Once again, a phonological analysis involving a floating autosegment at the right edge of the trigger is highly implausible, since such a floating element would have to marked as applying to only three lexical items and to no other words.

Irregular targets in Irish. Forms of the Irish verb 'to say' that begin with *d-* (e.g. *deir* (present) and *dúirt* (past)) do not undergo Lenition in the standard language after particles that otherwise cause Lenition, such as the negative particle *ní* and the direct relative particle *a*: *ní deirim* 'I do not say' (**ní* ***dh****eirim*), *nuair a dúirt tú* 'when you said' (**nuair a* ***dh****úirt tú*). If leniting proclitics like *ní* end in a floating autosegment, it is difficult to explain why those features fail to trigger Lenition in this word. Other words that regularly resist Lenition are *méid* 'amount', *Dé* '-day' (in names of days), and *t(o)igh* 'at the house of' (Ó Siadhail 1989: 114).

In Old Irish, the normal Lenition of s was h, as it is in Modern Irish. But the word *siur* 'sister' exceptionally became *fiur* rather than *[hiur] under Lenition.[20] If a feature or feature bundle is supposed to be responsible for debuccalization, why is there no debuccalization in

[20] There are a few other words that show s □ f Lenition, but only word-internally, e.g. *seiser* 'group of six people' vs. *mór-feiser* 'group of seven people' (lit. 'large group of six people') and *sephainn* [s□efəɴ□] 'played' (reduplicated preterite of *seinn-*).

this word? And when debuccalization fails, why should the coronal fricative become a labial fricative?

The Irish irregular verb *faigh* 'get, find' is irregular not only in its inflection but in its mutation behavior as well. Whereas the negative particle *ní* causes Lenition of every other verb in the language that begins with a lenitable consonant, it causes Eclipsis of *faigh*, as in the examples in (38).

(38) Eclipsis of *faigh* after *ní*

ní **bhf**aighidh sé	'he will not get/find'
ní **bhf**uair sé	'he did not get/find'

Other leniting particles, such as the direct relative particle *a*, do lenite *faigh* as expected, e.g. *nuair a **fh**aigheann siad* 'when they get/find'. The behavior of *faigh* after *ní* is unexplainable under a phonological analysis of mutation: if *ní* ends with a Lenition-triggering floating autosegment, or if it is always followed by a silent Lenition-triggering morpheme, why should the Lenition-triggering element switch to an Eclipsis-triggering element before the forms of the verb *faigh*?

In English loanwords, Lenition applies only if it does not cause debuccalization or deletion; in other words, Lenition does not apply to English loanwords that begin with t, d, s, or f.[21] The examples in (39) are taken from de Bhaldraithe (1953/1977: 257 f.).

(39) Lenition of English words only without debuccalization/deletion

a Mhary	'Mary!' (vocative)
a Bhridgy	'Bridgy!' (vocative)
a Mhike	'Mike! (vocative)
faoi Dan	'about Dan'
droch-tae	'bad tea'
tigh Dick	'at Dick's house'
déanta de *twine*	'made of twine'
aon *fag*	'any fag (cigarette)'
Seán Frank	'Seán (son) of Frank'
a Fanny	'Fanny!' (vocative)
a Sally	'Sally!' (vocative)
a Sarah	'Sarah!' (vocative)

If Lenition were an automatic phonological process, we would expect it to apply to English words used in Irish as regularly as it applies to native Irish words. A case could be made within a phonological analysis that the reason English t, d, s, f fail to lenite is recoverability, which could be expressed in OT terms as high-ranking faithfulness to place of articulation. Such an argument would require the assumption that faithfulness constraints on foreign words are higher ranked than faithfulness constraints on native words, an argument that has been made in slightly different forms by Davidson & Noyer (1997), Itô & Mester (1999), and Féry (2003). If other evidence were stronger that Lenition is truly a phonological process, then an analysis based on different rankings of faithfulness constraints in loanwords and native words could be made here. But, as I have been showing throughout this paper, phonological analyses

[21] Irish speakers generally use a dental articulation for velarized t, d in Irish words and an alveolar articulation for t, d in English words. It is sometimes claimed that this is the reason English t, d fail to lenite, namely because their place of articulation is different. However, in some Munster dialects, palatalized t, d are alveolar also in Irish words (Ó Cuív 1944: 35 f.; Holmer 1962: 34 f.; Ó Sé 2000: 13 f.), and Irish words do undergo Lenition.

of the mutations are very problematic, and the data in (39), rather than calling for an analysis within a phonological treatment, are instead additional evidence against the mutations being phonological processes at all. As a functional explanation, the intuition that foreign words resist Lenition if the phonological changes are "too extreme" is strong; but since the mutations in general resist a formal phonological analysis, we unfortunately cannot convert that functional intuition into a formal statement.

Irregular targets in Welsh. As in Irish, English words in Welsh resist mutation if the effect is deletion (i.e. if they begin with g), as shown in (40a). This restriction applies to some monosyllabic native Welsh words beginning with g as well. Foreign place names usually do not get mutated (although there is some variation in this respect) regardless of their initial consonant, as shown in (40b), although Welsh place names (including the Welsh names of places outsides Wales) do get lenited: *i Fanceinion* 'to Manchester' (Manceinion), *i Fryste* 'to Bristol' (Bryste). Personal names usually resist mutation whether they are of Welsh or foreign origin ((40c)), although in formal texts they can be mutated. In the literary language at least, the adjective *braf* 'fine' resists SM as well.

(40) Words resisting SM in Welsh

a.	Foreign (and some monosyllabic Welsh) words beginning with g	
	garej	'garage'
	gêm	'game'
	gôl	'goal'
	gro	'gravelly shore'
b.	Foreign place names	
	i **B**uffalo	'to Buffalo'
	i **B**onn	'to Bonn'
	yn **B**erlin	'in Berlin'
c.	Personal names	
	i **D**afydd	'to Dafydd'
d.	braf	'fine'

As with the foreign words that resist Lenition in Irish, the Welsh forms in (40) could conceivably be analyzed as belonging to a stratum of the Welsh lexicon to which faithfulness applies more stringently than to native words, if a phonological analysis of mutations were otherwise plausible. But as has been shown throughout this paper, such a phonological analysis is not plausible, and the functional intuition that foreign words resist alteration more than native words do must remain unformalized.

In this section we have seen several ways in which the Celtic mutations fail to exhibit behavior typical of phonological processes: they do not target natural classes of features, have uniform, predictable effects, or reduce phonological markedness in any obvious way. Rather, they are idiosyncratic and arbitrary, both in their environments and in their effects. For these reasons it is preferable to view the mutations not as phonological processes but as morphological effects.

4 Mutations as morphological effects

In the past section we saw a number of reasons why the most nearly plausible phonological analysis of the mutations, namely that they are triggered by floating autosegments, cannot be accurate. In this section I will outline a preferable analysis, according to which the mutated forms of words are listed in the lexicon alongside the radical forms. The grammar then picks the correct allomorph for any given environment. Thus, in spite of the phonological appearance of the mutations, they are in fact entirely outside the phonology; their phonological element can be explained only historically, not synchronically. The mutations are properties of the lexicon, which consists not of roots and affixes, but rather of whole words listed in all their actual surface forms and connected to each other through their shared properties, a view of the lexicon supported by Bybee (1985, 2001), Singh (1987, 1996), Bochner (1993), Ford & Singh (1996), and Ford et al. (1997).

4.1 Views of lexical organization

Probably the most widespread view of the lexicon in generative phonology today is the Item-and-Arrangement (IA) view (Hockett 1958; see also Spencer 1998 for discussion), according to which roots and affixes are listed in the lexicon under unique underlying representations (URs). These roots and affixes may be joined together and then phonological rules (in derivational phonology) or constraints (in constraint-based phonology like OT) apply to generate the surface form. According to the IA view, the alternation seen, for example, in Irish *bróg* [bro:g] 'shoe' ~ *bhróg* [vro:g] 'shoe (lenited) ~ *mbróg* [mro:g] 'shoe (eclipsed)' is to be analyzed thus: the Irish lexicon includes a UR /bro:g/ and a variety of Lenition- and Eclipsis-triggering morphemes, some of which may consist entirely of a floating autosegment, others of which may include a floating autosegment at their right edge. When a mutation-triggering morpheme comes into contact with a potential host word, like /bro:g/, phonological processes (rules, constraint interactions, etc.) apply in such a way as to result in the surface form [vro:g] in Lenition environments and the surface form [mro:g] in Eclipsis environments. If neither process applies then the surface form is radical [bro:g].

In contrast with the IA view, the Item-and-Process (IP) view considers affixal morphemes to be processes that apply to roots in ways that are not always linearly concatenative. An IP view of the Celtic mutations would treat them as processes in themselves that manifest certain morphological properties; there is no assumption of floating autosegments triggering the mutations. Adopting this view alleviates many of the problems discussed above associated with a phonological analysis, but it still assumes that mutated forms can be derived from radical forms. Given the wide variety of phonological changes that a single mutation can cause (e.g. spirantization, debuccalization, deletion, and "laxing" in the case of Irish Lenition) as well as the numerous exceptions and irregularities discussed in § 3.4 above, even the IP view falls short of a satisfying analysis. Moreover, while the IP view of morphology accounts nicely for nonconcatenative morphology like English *man–men* or *write–wrote*, holding that the properties "plural" or "past" are manifested by a vowel alternation instead of a segment, extending that analysis to pairs like Irish *bróg–bhróg* is difficult since the latter is not a manifestation of a single morphological property.

The word-based view endorsed here contrasts with both the IA and the IP views of morphology. It holds that lexical items are listed in the lexicon under all of the forms in which they may surface. Thus affixation, for example, is not a process separate from the lexicon: morphologically complex forms like *walks, walked, walking* are not derived from *walk+s, walk+ed, walk+ing* etc., but instead are listed whole in the lexicon. Similarly, mutated forms like *bhróg* and *mbróg* are not derived from *bróg* in any way, but are listed alongside it in the Irish lexicon. The job of the grammar is then not to change *bróg* into *bhróg* or *mbróg* but rather to determine which form is used where.

4.2 Mutation selection parallel to case selection

The situation, I suggest, is parallel to that of case selection in languages like Latin, Russian, and German. Consider, for example, the dative case in German. As illustrated in (41), the German dative is used with indirect objects (41a), with the complements of certain verbs and adjectives (41b) – (41c), and with prepositions indicating non-goal-oriented location (41d). In most instances the dative case of a full NP is marked morphologically on the determiner, not the noun itself. Examples are from Helbig & Buscha (1991).

(41) Dative case in German

a. Indirect objects

Der	Dozent	traut	dem	Studenten	die	Arbeit	zu.
the	instructor	believes-capable	the$_{DAT}$	student	the$_{ACC}$	work	PRT

‘The instructor believes the student capable of the work.’

Er	bietet	dem	Freund	eine	Zigarette	an.
he	offers	the$_{DAT}$	friend	a$_{ACC}$	cigarette	PRT

‘He offers the friend a cigarette.’

b. Complements of certain verbs

Er	begegnet	dem	Freund.
he	meets	the$_{DAT}$	friend

‘He meets the friend.’

Sie	hilft	dem	Freund.
she	helps	the$_{DAT}$	friend

‘She helps the friend.’

c. Complements of certain adjectives

Der	Schüler	ist	seinem	Vater	ähnlich.
the$_{NOM}$	schoolboy	is	his$_{DAT}$	father	similar

‘The schoolboy is similar to his father.’

Er	ist	dem	Direktor	bekannt.
he	is	the$_{DAT}$	director	known

‘He is known to the director.’

d. Prepositions indicating non-goal-oriented location

Das	Heft	liegt	im	Schrank.
the$_{NOM}$	booklet	lies	in-the$_{DAT}$	cupboard

‘The booklet is (lying) in the cupboard.’

Der	Schrank	steht	an	der	Wand.
the$_{NOM}$	cupboard	stands	against	the	wall

‘The cupboard is (standing) against the wall.’

Das	Kind	läuft	auf	der	Straße.
the$_{NOM}$	child	runs	on	the$_{DAT}$	street

‘The child is running on the street.’ (i.e. running around there)

With (41d) may be contrasted the forms in (42), where we see that the object of a preposition indicating goal-oriented motion is in the accusative.

(42) Accusative after prepositions indicating goal-oriented motion

Er	legt	das	Heft	in	den	Schrank.
he	puts	the$_{ACC}$	booklet	in	the$_{ACC}$	cupboard

‘He puts the booklet in the cupboard.’

Sie schieben den Schrank an die Wand.
they push the$_{ACC}$ cupboard against the$_{ACC}$ wall
'They push the cupboard against the wall.'

Das Kind läuft auf die Straße.
the$_{NOM}$ child runs on the$_{ACC}$ street
'The child is running onto the street.' (i.e. running towards it)

Interestingly, the preposition *zu* 'to' always governs dative case, even when goal-oriented motion is indicated, as shown in (43).

(43) Wir gehen zum Bahnhof.
we go to-the$_{DAT}$ railroad-station
'We're going to the railroad station.'

Thus, case selection in German can be determined by either syntactic ((41a), (41d), (42)) or lexical ((41b), (41c), (43)) criteria. Mutation selection in Celtic languages, I argue, works the same way. Just as prepositions in German can subcategorize for what case they govern (the one in (43) even overriding syntactic generalizations), so determiners, prepositions, and other proclitics in the Celtic languages can subcategorize for what mutation grade they govern. For example, the feminine singular definite article in Welsh governs the lenited form of a noun (unless it begins with ɬ or r̥); all other forms of the definite article govern the radical form. In Irish, possessive pronouns of the first person singular, second person singular, and third person masculine singular govern the lenited form, that of the third person feminine singular governs the radical form, and those of the plural govern the eclipsed form. And just as syntactic position can determine case in German, so can it determine mutation grade in Celtic languages: for example, the first word in an NP following a c-commanding or sister XP in Welsh (assuming the XPTH is correct) appears in the SM form.

Allowing the morphology and the syntax to directly choose mutation grade has a number of advantages over the hypothesis that mutation is triggered by floating autosegments. For one thing, we are not required to posit silent morphemes in environments where there is no independent evidence for them, nor do we have to resort to highly idiosyncratic phonology in order to achieve the alternations attested. When a feminine noun is lenited after the definite article, as are any adjectives modifying that noun, it is because the syntax of feminine NPs requires it, not because feminines end in a floating autosegment. The nonadjacency cases of §3.3 are easily explained under this view: in a phrase like *ár dhá gcuid* 'our two parts', see (26e), *ár* requires its noun to appear in the eclipsed form, while *dhá* requires its noun to appear in the lenited form. We may hypothesize that the requirement of *ár* takes precedence, perhaps because it is higher in the tree than *dhá*. At any rate, the fact that the trigger *ár* is not adjacent to its target *mbád* is not a problem under this view. The same holds true of the other nonadjacency cases like *trí shioc agus* ***sh****neachta* 'through frost and snow' and *Cá bhfuil mo fuckin'* ***sh****eaicéad?* 'Where's my fuckin' jacket?', where the mutation trigger still governs its target even without being adjacent to it.

The irregular behavior of mutation triggers discussed in §3.4 can be analyzed by fine-tuning the subcategorization frames of the triggers (e.g. the numbers 3–6 subcategorize for the lenited form of singular nouns but the radical form of plural nouns in Irish; the particles *ni, na,* and *oni* subcategorize for the AM form of a word in Welsh where it is available, otherwise the SM form, etc.) The irregular behavior of mutation targets can be analyzed by proposing that individual lexical items can have mutation allomorphs that deviate from the usual pattern. For example, the verb 'to say' in Modern Irish has allomorphs marked "lenited" that nevertheless begin with d rather than expected ɣ; the noun ‘sister’ in Old Irish has an allomorph marked “lenited” that begins with f rather than expected h; and so on.

Thus the mutations are like inflections, but orthogonal to them. According to context, the nominative of ‘friend’ in Irish is *cara, chara* or *gcara*, the genitive *carad* or *charad* etc. I am *not* arguing that mutation is a form of Case-marking, as Zwicky (1984) and Roberts (1997, in press) did for Welsh. Instead, I am asserting that mutated forms are listed in the lexicon in a manner parallel to the listing of inflected forms.

4.3 Defending a nonphonological analysis

Ball & Müller (1992: 123 f.) anticipate the present analysis in a section considering whether Welsh mutations may be outside the phonology. They criticize this idea thus:

> While this on the face of things does remove mutations from the phonology, we are left with sets of forms forms for each lexical item that are clearly very similar phonologically. If we resort to suppletion (i.e. implicitly claiming they are all totally unrelated) the resultant analysis would be seen as eccentric to say the least, and as inadequate in that it refused to account for an obvious set of similarities between the forms. If, on the other hand, we attempt to link the forms, we can only do so via a phonological description. It would seem, therefore, that whatever phonological approach we adopt, and wherever the rules are situated, there is no adequate account of mutations that does not involve some kind of phonological formalism.

It would indeed be eccentric and inadequate to claim that the mutated and radical forms of words were totally unrelated and to refuse to account for the similarities. However, it is not the case that the relationships and similiarities among the form can be accounted for *only* phonologically. Generalizations like “nonlenited [−cont] → lenited [+cont]” are still expressible under the present account, but they are not phonological rules. Instead, they are statements of behavior in the Irish lexicon which have the status of tendencies. During the acquisition process, speakers pick up on alternations like p ~ f and k ~ x in the same morphosyntactic environments and can spread them analogically to new forms without either adding phonological rules or setting up phonological constraint interactions to handle these alternations. Other Lenition statements are made more specifically, as shown in (44). Again, these are not statements of phonological rules or processes of any kind; they are statements of tendencies in the Irish lexicon that speakers deduce from the lenited/nonlenited pairs they learned during acquisition.

(44) Additional Lenition generalizations for Irish

nonlenited [coronal, −voi] → lenited h
nonlenited d → lenited ɣ
nonlenited f → lenited ∅
nonlenited m → lenited v

Idiosyncratic exceptions to these generalizations, such as the blocking of Lenition in *deir* ‘says’ and related forms in Irish, must be learned individually, and will tend to regularize. Indeed, some Ulster Irish texts in the Tobar na Gaedhilge database (Ó Duibhín 2003) do have lenited forms like *níor dhúirt* ‘did not say’ for standard *níor dúirt*. The Old Irish pair *siur ~ fiur* ‘sister (radical–lenited)’ with an idiosyncratic s ~ f alternation has been regularized in Modern Irish as *siúr ~ shiúr* with a regular s ~ h alternation and in Scots Gaelic as *piuthar ~ phiuthar* with a regular p ~ f alternation.

As for lexical economy, even though speakers may have a listed f-initial allomorph marked “lenited” corresponding to every (or almost every) p-initial allomorph marked “radical”, their awareness of the generalization means that the f-initial allomorph does not necessarily “cost anything.” If only independent (“new”) information adds to the complexity of the grammar, as Bochner (1993) has proposed, then for a pair like /pa:r□k□~ fa:r□k□/ ‘field’, only /pa:r□k□/ and the Lenition generalization are counted; /fa:r□k□/ does not add to complexity in spite of being accessible to the speaker as a listed form in the lexicon. The interested reader is referred to Bybee (1988) for a general response to the charge of uneconomicalness in word-based morphology.

Questions may also arise concerning the predictive power of the present analysis. Since I have removed the mutations from the restrictions of the phonology and put them in the lexicon, where virtually everything is idiosyncratic, some readers may wonder if there are any limits on what kinds of alternations I predict can happen; indeed, it may seem that I am predicting languages where, in the lexicon at least, anything can alternate with anything. To this I respond that morphologized remnants of historical phonological changes are full of very peculiar things cross-linguistically. Consider English velar softening: what originated as a palatalization of velar stops before front vowels in late variety of Vulgar Latin remains as a set of k ~ s and g ~ ǰ alternations that are no longer phonologically predictable (see Green 2002 for discussion). As mentioned at the beginning of the paper, the strongest theory of phonology concerns itself only with the interaction of markedness and faithfulness. To allow phonology to be powerful enough to account for the quirkiest phoneme alternations is to weaken phonological theory to the point of being unfalsifiable. The lexicon, which is by definition arbitrary, is the natural home of idiosyncrasies and language-specific peculiarities; the phonology is not. The only limits on alternations found in the lexicon are imposed by what alternations historical sound change is likely to result in.

5 Conclusions

In this paper I have argued that the traditional view of the Celtic mutations as phonological processes that apply in morphosyntactically determined environments is not tenable. The mutations cannot be shown to reflect the interaction of faithfulness with universal markedness principles, in violation of the strong OT-phonology hypothesis that all phonological processes reflect such an interaction. The morphosyntactically triggered Lenition of Manx contrasts sharply with an intervocalic lenition process in the same language, which is palpably phonological in both its environment and its effects. In all the Celtic languages, the morphosyntactically triggered mutation alternations themselves are not expressible in terms of predictable changes of phonological features, nor can the environments of the changes be convincingly attributed to floating autosegments, as has frequently been claimed since Lieber (1987). Furthermore, the large number of irregularities and exceptions among both triggers and targets strongly suggests that the mutations are properties of the lexicon, not the phonology. Instead, the Celtic mutations are encoded directly in the items listed in the lexicons of the languages, resulting in patterns that are discernible to speakers and that can spread analogically to new forms, even though there are no explicit rules or constraint interactions forcing the mutations. The grammar of each language allows proclitics and syntactic positions to determine which mutation grade of a lexical item is grammatical in which environment, in a manner parallel to the selection of Case by prepositions and syntactic positions in languages like German.

Appendix: Some environments of mutations in Irish and Welsh

The following list is representative, not exhaustive. Most examples come from Christian Brothers (1960) or Ó Dónaill (1977) for Irish and King (1993) or Thorne (1993) for Welsh.

(1) Mutations of nouns after the definite article (see (3) – (4) in the main text)

(2) Mutations of nouns after possessive pronouns in Irish

‘my’	Lenition	mo **ch**os	‘my leg’	(cos)
‘your’ (sg.)	Lenition	do **bh**róg	‘your (sg.) shoe’	(bróg)
‘his’	Lenition	a **bh**ríste	‘his trousers’	(bríste)
‘her’	Radical (but *h* before a vowel)	a **g**úna	‘her gown’	(gúna)
		a **h**ál	‘her litter’	(ál)
‘our’	Eclipsis	ár **mb**ád	‘our boat’	(bád)
‘your’ (pl.)	Eclipsis	bhur **dt**each	‘your (pl.) house’	(teach)
‘their’	Eclipsis	a **gc**airde	‘their friends’	(cairde)

(3) Mutations of nouns after possessive pronouns in Welsh

‘my’	NM	fy **mh**lant	‘my children’	(plant)
‘your’ (sg.)	SM	dy **d**ŷ	‘your (sg.) house’	(tŷ)
‘his’	SM	ei **f**am	‘his mother’	(mam)
‘her’	AM	ei **ch**i	‘her dog’	(ci)
‘our’	Radical	ein **b**ara	‘our bread’	(bara)
‘your’ (pl.)	Radical	eich **d**illad	‘your (pl.) clothes’	(dillad)
‘their’	Radical	eu **g**ardd	‘their garden’	(gardd)

(4) Mutations of nouns after prepositions in Irish

a	Lenition	a **dh**íol	‘to sell’	(díol)
de		de **Sh**orcha	‘from Sorcha’	(Sorcha)
do		do **gh**asúr	‘to a boy’	(gasúr)
faoi		faoi **bh**ord	‘under a table’	(bord)
mar		mar **dh**uine	‘as a person’	(duine)
ó		ó **bh**éal	‘from a mouth’	(béal)
roimh		roimh **mh**aidin	‘before morning’	(maidin)
trí		trí **Bh**éarla	‘through English’	(Béarla)
um		um **Sh**amhain	‘in November’	(Samhain)
ach	Radical (vowel-final ones add *h*- to a following vowel)	ach **T**omás	‘except Tomás’	(Tomás)
ag		ag **S**eán	‘at Seán’	(Seán)
amhail		amhail **b**ean	‘like a woman’	(bean)
as		as **b**aile	‘out of town’	(baile)
chuig		chuig **T**adhg	‘to Tadhg’	(Tadhg)
chun		chun **P**ádraig	‘to Pádraig’	(Pádraig)
dar		dar **f**éasóg m’athar	‘by my father’s beard’	(féasóg)

go		go **S**asana	'to England'	(Sasana)
		go **h**Éirinn	'to Ireland'	(Éirinn)
le		le **t**eacht	'with an approach'	(teacht)
		le **h**airgead	'with money'	(airgead)
murach		murach **S**íle	'were it not for Síle'	(Síle)
seachas		seachas **g**eimhreadh	'besides winter'	(geimhreadh)
i	Eclipsis	i **mb**aile	'in town'	(baile)
ar	See (31) – (33) in the main text			
gan				
thar				

(5) Mutations of nouns after prepositions in Welsh

â	AM	â **ch**yllell	'with a knife'	(cyllell)
gyda		gyda **ph**lant	'with children'	(plant)
tua		tua **ph**um pwys	'about five pounds'	(pum)
am	SM	am **f**is	'for a month'	(mis)
ar		ar **f**wrdd	'on a table'	(bwrdd)
at		at **f**eddyg	'to a doctor'	(meddyg)
dan		dan **dd**ylanwad ei rieni	'under the influence of his parents'	(dylanwad)
dros		dros **b**ont	'over a bridge'	(pont)
gan		gan **g**i	'by a dog'	(ci)
heb		heb **w**ydr	'without glass'	(gwydr)
hyd		hyd **dd**iwedd mis Mehefin	'until the end of June'	(diwedd)
i		i **d**ad Eleri	'to Eleri's father'	(tad)
o		o **F**angor	'from Bangor'	(Bangor)
tan		tan **f**is Tachwedd	'until the month of November'	(mis)
trwy		trwy **f**enyn	'through butter'	(menyn)
wrth		wrth **dd**esg	'by a desk'	(desg)
cyn	Radical	cyn **d**iwedd yr arganddosfa	'before the end of the show'	(diwedd)
efo		efo **p**lant	'with children'	(plant)
ger		ger **C**aerdydd	'near Cardiff'	(Caerdydd)
mewn		mewn **t**ŷ	'in a house'	(tŷ)
rhag		rhag **c**ywilydd	'for shame'	(cywilydd)
rhwng		rhwng **C**ymru a Lloegr	'between Wales and England'	(Cymru)
yn	NM	yn **Nh**alybont	'in Talybont'	(Talybont)

(6) Mutations of nouns after numbers 2–10 in Irish (noun in singular form) (but see (27) – (28) in the main text)

2	Lenition	dhá **th**each	‘two houses’	(teach)
3	Lenition	trí **bh**ád	‘three boats’	(bád)
4	Lenition	ceithre **bh**ó	‘four cows’	(bó)
5	Lenition	cúig **ph**unt	‘five pounds’	(punt)
6	Lenition	sé **mh**í	‘six months’	(mí)
7	Eclipsis	seacht **gc**apall	‘seven horses’	(capall)
8	Eclipsis	ocht **n-**asal	‘eight donkeys’	(asal)
9	Eclipsis	naoi **gc**at	‘nine cats’	(cat)
10	Eclipsis	deich **bp**eann	‘ten pens’	(peann)

(7) Mutations of nouns after numbers 1–10 in Welsh (noun in singular form)

1, masc.	Radical	un **c**effyl	‘one horse’	(ceffyl)
1, fem.	SM (except of *ll*, *rh*)	un **g**ath	‘one cat’	(cath)
2, masc.	SM	dau **g**effyl	‘two horses’	(ceffyl)
2, fem.	SM	dwy **g**ath	‘two cats’	(cath)
3, masc.	AM	tri **ph**arsel	‘three parcels’	(parsel)
3, fem.	Radical	tair **c**einiog	‘three pence’	(ceiniog)
4, masc.	Radical	pedwar **b**laidd	‘four wolves’	(blaidd)
4, fem.	Radical	pedair **b**uwch	‘four cows’	(buwch)
5	Radical	pum **d**yn	‘five men’	(dyn)
6	AM	chwe **ch**effyl	‘six horses’	(ceffyl)
7	Radical	saith **p**ryf	‘seven worms’	(pryf)
8	Radical	wyth **t**roed	‘eight feet’	(troed)
9	Radical	naw **m**illtir	‘nine miles’	(milltir)
10	Radical	deg **g**ŵydd	‘ten geese’	(gŵydd)

(8) Mutations of attributive adjectives after nouns in Irish (e.g. *cóir* ‘just’) (cf. (19) in the main text)

Masc. nom. sing.	Radical	fear **c**óir	‘a just man’
Masc. gen. sing.	Lenition	fir **ch**óir	‘of a just man’
Fem. nom. sing.	Lenition	máthair **ch**óir	‘a just mother’
Fem. gen. sing.	Radical	máthar **c**óra	‘of a just mother’
Dat. sing. (after definite article)	Optional Lenition if the noun is overtly lenited, otherwise radical	don fhear **c(h)**óir	‘to the just man’
		don duine **c**óir	‘to the just person’
Nom. pl.	Lenition if the noun ends in a palatalized consonant, otherwise radical	fir **ch**óra	‘just men’
		máithreacha **c**óra	‘just mothers’
Gen. pl.	Radical	fear **c**óir	‘of just men’
		máithreacha **c**óra	‘of just mothers’

(9) Mutations of attributive adjectives after nouns in Welsh (e.g. *mawr* 'big')

Masculine singular	Radical	bwrdd **m**awr	'a big table'
Feminine singular	SM	torth **f**awr	'a big loaf'
Plural	Radical	byrddau **m**awr	'big tables'
		torthau **m**awr	'big loaves'

(10) Mutations of regular finite verb forms in Irish

a. ***Radical*** in present and future tenses without particle

Feicim anois iad. (feic-)
see-PRES-1SG now them
'I see them now.'

Tiocfaidh Somhairle anocht. (tiocf-)
come-FUT S. tonight
'Somhairle will come tonight.'

b. ***Lenition*** in past, imperfect and conditional tenses without particle (except past autonomous) (cf. (29) in the main text)

Thosaigh sí ag gol. (tosaigh-)
begin-PAST she crying
'She began to cry.'

Deisíodh an rothar. (deisigh-)
repair-PAST-AUT the bicycle
'The bicycle was repaired.'

Thagadh an galtán gach lá anuraidh. (tag-)
come-IMPF the steamer every day last-year
'The steamer used to come every day last year.'

Bhrisfí mo chos murach tusa. (bris-)
break-COND-AUT my leg if-not-for you
'My leg would be broken if it weren't for you.'

c. ***Lenition*** in all tenses after *a* (direct relative), *má* 'if', *ní* 'not'

an fear a **ch**uireann síol (cuir-)
the man DIR.REL put-PRES seed
'the man who sows seed'

Dúirt sé má **ch**asfadh sé liom go dtabharfadh sé an scéal dom.
said he if meet-CONDIT he with-me that give-CONDIT he the story to-me (cas-)
'He said that if he met me he would give me the message.'

Ní **fh**aca sé mé. (fac-)
not see-PAST he me
'He did not see me.'

d. ***Eclipsis*** in all tenses after *a* (indirect relative), *an* (interrogative), *cá* 'where', *dá* 'if', *go* 'that', *nach* 'that not', *mura* 'unless', *sula* 'before'

an gort a **gc**uirfidh sé an síol ann (cuir-)
the field IND.REL put-FUT he the seed in-it
'the field that he will sow the seed in'

An **dt**agann sé? (tag-)
INTERR come-PRES he
'Does he come?'

Cá **nd**eachaigh sé? (deachaigh-)
where go-PAST he
'Where did he go?'

dá **bhf**ágainn agat é (fág-)
if leave-IMPF-1SG with-you it
'if I had left it with you'

ar eagla go **mb**einn déanach (bei-)
for fear that be-CONDIT-1SG late
'for fear that I would be late'

e. ***Lenition*** in past tense (except autonomous) after *ar* (indirect relative; interrogative), *cár* 'where', *gur* 'that', *murar* 'unless', *níor* 'not', *sular* 'before'

an gort ar **ch**uir sé an síol ann (cuir-)
the field IND.REL put-PAST he the seed in-it
'the field that he sowed the seed in'

Cár **ch**uir tú é? (cuir-)
where put-PAST you it
'Where did you put it?'

Sílim gur **bh**ris an gol air. (bris-)
think-PRES-1SG that break-PAST the weeping on-him
'I think that he burst into tears.'

murar **ch**aill sé é (caill-)
if-not lose-PAST he it
'if he didn't lose it'

Níor **ch**reid sé mé. (creid-)
not believe-PAST he me
'He didn't believe me.'

sular **ch**eannaigh mé an leabhar (ceannaigh-)
before buy-PAST I the book
'before I bought the book'

(11) Mutations of regular finite verb forms in Welsh

a. ***SM*** in affirmative forms after particles *mi/fe*

Mi **b**ryna i 'r tlws i ti. (pryna)
AFF buy-FUT-1SG I the jewel for you
'I'll buy the jewel for you.'

Fe **g**lywes i 'r newyddion ar y radio bore 'ma.
AFF hear-PAST-1SG I the news on the radio this morning
'I heard the news on the radio this morning.' (clywes)

b. ***Optional SM*** in affirmative forms without *mi/fe*

Gollais/**C**ollais i 'r tocyn. (collais)
lose-PAST-1SG I the ticket
'I lost the ticket.'

Allwch/**G**allwch chi weld e o fan hyn. (gallwch)
can-PRES-2PL you see-VN him from here
'You can see him from here.'

c. ***SM*** in interrogative forms

Welsoch chi ddyn yn mynd heibio gynnau? (gwelsoch)
see-PAST-2PL you man going past just now
'Did you see a man go past just now?'

d. ***AM*** where possible, otherwise ***SM*** in negative forms where *ni* is suppressed (cf. (34) in the main text)

Chododd o mo 'i ben o'r croesair. (cododd)
raise-PAST-3SG he NEG his head from the crossword
'He did not raise his head from the crossword.'

Wnes i ddim byd na ddylwn i. (gwnes)
do-PAST-1SG I NEG anything NEG-REL ought-1SG I
'I didn't do anything I ought not (to have done).'

e. ***Radical*** after *hyd* 'until, as long as', *felly* 'so', *os* 'if', *pe* 'if'

hyd **g**welech chi faes chwarae ar y dde (gwelech)
until see-FUT-2PL you playing field on the right
'until you see a playing field on the right'

felly **b**yddai 'r gallu i siarad Cymraeg yn ddymunol
so be-COND-3SG the ability to speak-VN Welsh PRED desirable
'so the ability to speak Welsh would be desirable' (byddai)

os **d**aw Freddie i'r parti (daw)
if come-FUT F. to the party
'if Freddie comes to the party'

pe **b**yddai Freddie 'n dod i'r parti (byddai)
if be-COND F. coming to the party
'if Freddie were coming to the party'

f. ***SM*** after *pan* 'when'

pan **d**ynnith hi 'r llun (tynnith)
when pull-FUT-3SG she the picture
'when she takes the picture'

(12) Other proclitic-triggered Lenitions in Irish

a. nouns and names after the vocative particle *a*

a **bh**ean	'O woman'	(bean)
a **fh**eara	'O men'	(feara)

b. nouns after certain determiners

gach uile **fh**ocal	'every word'	(focal)
aon **ch**iall	'any sense'	(ciall)

c. nouns and adjectives after irrealis copular particles

ba **dh**uine mór é	'He was a great man'	(duine)
ba **bh**reá é	'it was fine'	(breá)

(13) Some syntax-triggered Lenitions in Irish

a. definite genitive NPs (cf. (20) in the main text)

muintir **Sh**eáin ‘Seán’s family’ (Seáin)
mac **fh**ear an tí ‘the landlord’s son’ (fear)

b. adjectives and genitive nouns after plural nouns that end in a palatalized consonant

lachain [laxən] **fh**iáine ‘wild ducks’ (fiáine)
buidéil [bide:l] **bh**ainne ‘bottles of milk’ (bainne)

c. adjectives and genitive nouns after a feminine singular noun

spideog **bh**eag ‘a small robin’ (beag)
glac **th**airní ‘a handful of nails’ (tairní)

d. adjectives after a noun following a number from 2–19

dhá naomhóg **dh**ubha ‘two black coracles’ (dubha)

(14) Other SMs in Welsh

a. nouns and adjectives after the predicative particle *yn* (does not affect *ll* and *rh*) (cf. (35c) in the main text)

Mae Llundain yn **dd**inas fawr. (dinas)
is London PRED city big
‘London is a big city.’

Mae Llundain yn **f**awr. (mawr)
is London PRED big
‘London is big.’

b. nouns and names used vocatively

Dewch fan hyn, **b**lant! (plant)
come-IMPV-PL here children
‘Come here, children!’

c. nouns after adjectives (the marked order)

yr Hen **D**estament (Testament)
‘the Old Testament’

d. the first word of an adverbial phrase of time or manner

ddwy flynedd yn ôl (dwy)
‘two years ago’

e. a noun after a c-commanding or sister XP (see (21) – (25) in the main text)

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Anti-Structure Preservation Effects in Optimality Theory[*]

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Abstract

The present study examines a particular kind of rule blockage – referred to below as an 'anti-structure-preservation effect'. An anti-structure-preservation effect occurs if some language has a process which is preempted from going into effect if some sequence of sounds [XY] would occur on the surface, even though other words in the language have [XY] sequences (which are underlyingly /XY/). It will be argued below that anti-structure-preservation effects can be captured in Optimality Theory in terms of a general ranking involving FAITH and MARKEDNESS constraints and that individual languages invoke a specific instantiation of this ranking. A significant point made below is that while anti-structure-preservation effects can be handled straightforwardly in terms of constraint rankings they typically require ad hoc rule-specific conditions in rule-based approaches.

1 Introduction

In many languages one can observe regular phonological processes which fail to go into effect in some well-defined context – a situation which is usually referred to in the literature as a *blocking effect*. What is typically the case with blocking effects is that the process does not apply if some structure would be created which does not exist at all in that particular language. Thus, if a phonological rule introduces the sound [X] in a language L_1 and if the rule is blocked in words in which [Y] would surface in the neighborhood of the sound [X], then the usual assumption is that the blocking effect occurs because there are no surface sequences of [XY] (or [YX]) in L_1.

In this article I discuss blocking effects which are similar to the one described above for L_1 with the sole exception that the language which has the blocking effect (L_2) has at least some words which contain the surface sequence [XY] (which corresponds to /XY/). In other words, the process introducing [X] is blocked in L_2 in some environment not *because* L_2 does not allow [XY], but instead it is blocked *even though* L_2 has some [XY] sequences. Thus, the [XY] sequences in L_2 can be thought of as being 'anti-structures', since these are precisely the sequences which are penalized by the constraint which is responsible for the blocking effects. For this reason the kind of blocking effect described above for L_2 is an example of what will be referred to below as an *anti-structure preservation effect*.

In this article I present several examples of anti-structure preservation effects and argue that they all fall out in an Optimality Theoretic (henceforth OT; Prince & Smolensky 1993) analysis given a general ranking scheme involving certain FAITH and MARKEDNESS constraints. It will be emphasized repeatedly below that many anti-structure preservation effects are problematic for rule based theories because they typically require *ad hoc*, rule-specific conditions.

This article is organized in the following way. In §2 I present a formal account of how blocking effects are captured in the OT model. In §3 I show that there is a general ranking for anti-structure preservation effects which can be derived by a simple permutation of two

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constraints in the general scheme for blocking effects. The remainder of that section is devoted to a series of case studies in which the general ranking for anti-structure preservation effects is instantiated with specific FAITH and MARKEDNESS constraints. §4 concludes.

2 Blocking effects

Many languages have regular processes which are blocked from applying if the output would contain some illicit structure. In this section I summarize briefly how such blocking effects are accounted for in the OT model (see McCarthy 2002: 26-29 for recent discussion, as well as Prince & Smolensky 1993: 33ff.).

In OT the change from some input to an output which is distinct is typically captured with the general ranking MARKEDNESS » FAITH. Thus, consider a language in which vowel-initial syllables are avoided on the surface by the epenthesis of a glottal stop, e.g. a sequence /apa/ surfaces as [ʔapa]. From a formal point of view these facts are captured by ranking the FAITH constraint DEP-C below the MARKEDNESS constraint ONSET: ONSET » DEP-C.

The blocking effects referred to above come about if the output of a particular process would violate a second constraint, which belongs either to the MARKEDNESS or to the FAITH family (e.g. a POSITIONAL FAITH constraint). Since the examples I discuss in this article all involve the domination of one MARKEDNESS constraint by another one, I restrict my discussion of blocking effects to the case of MARKEDNESS A » MARKEDNESS B, as opposed to FAITH » MARKEDNESS B. This general constraint schema for blocking effects is presented in (1). Here and below MARKEDNESS and FAITH are abbreviated as M and F respectively.

(1) General ranking for blocking effects (first version):

$$M_A \gg M_B \gg F_B$$

'F_B' is understood to be a collective term describing FAITH constraints which have the function of militating against the alternation of an input so that it would satisfy M_B.

An example of a blocking effect from Dutch illustrates the general ranking in (1) (see McCarthy 2002: 26-27, who cites Booij 1995). Dutch requires the ranking ONSET » DEP-C to capture formally the epenthesis of a glottal stop at the beginning of syllables which would be vowel-initial, as described in the hypothetical language above, e.g. Dutch /aorta/ 'aorta' surfaces as [ʔa.ˈʔor.ta]. The blocking effect can be observed in unstressed non-word-initial syllables, e.g. /farao/ 'Pharaoh' surfaces as [ˈfa.ra.o] and not as [ˈfa.ra.ʔo]. This blocking effect is captured by ranking ONSET below a MARKEDNESS constraint which prohibits [ʔ] from serving as the onset of an unstressed non-word-initial syllable (*ʔV).

The analysis described above is captured in the following two tableaus for [ʔa.ˈʔor.ta] and [ˈfa.ra.o]. These specific examples illustrate the general ranking in (1): M_A (*ʔV) » M_B (ONSET) » F_B (DEP-C).

(2)	/aorta/	*ʔV	ONSET	DEP-C
a.	[ʔa.ˈor.ta]		*!	*
b.	☞ [ʔa.ˈʔor.ta]			**

(3)

	/farao/	*ʔV	Onset	DEP-C
a.	☞ [ˈfa.ra.o]		*	
b.	[ˈfa.ra.ʔo]	*!		*

In the first tableau the form in (2b) is optimal because (2a) violates ONSET. In (3) candidate (3a) is correct because (3b) does not satisfy *ʔV.[1]

The blocking effects discussed above are usually assumed to be *pervasive* in the sense that the structure prohibited by M_A does not exist anywhere in the language at all. This tacit assumption is captured by ranking M_A ahead of FAITH constraints which militate against altering an input sequence so that it would satisfy M_A – FAITH constraints which I refer to below collectively as 'F_A'. The role of F_A with respect to the Dutch example can be illustrated by considering a hypothetical word with a sequence of unstressed (word-internal) [ʔV], say in a loanword of the form /ˈtaraʔo/. In this case an example of an F_A constraint would be IDENT-IO, since the change of the [ʔ] in the input /ˈtaraʔo/ to some other consonant would cause the output to be in line with *ʔV. e.g. /ˈtaraʔo/ → [ˈta.ra.ko]. Consider now the tableau in (4), in which the output form is one without the glottal stop:

(4)

	/ˈta.ra.ʔo/	*ʔV	IDENT-IO	Onset	DEP-C
a.	[ˈta.ra.ʔo]	*!			
b.	☞ [ˈta.ra.ko]		*		

In this tableau we can observe that the winner in (4b) is selected over the form which violates *ʔV (i.e. 4a) because of the ranking *ʔV » IDENT-IO (or more generally M_A » F_A). Note that F_A could be some other constraint which has the same function as IDENT-IO, i.e. a constraint which militates against a change which would bring the sequence into conformity with *ʔV, e.g. DEP-V, or MAX-C. (Note that in my analysis it is not crucial whether or not the correct output form is [ˈta.ra.ko], as in (4), or some other one, e.g. [ˈta.ra.o]).

The general ranking for blocking effects (taking now into consideration the pervasiveness of M_A) can now be stated in (5).

(5) a. General ranking for blocking effects:

M_A » M_B » F_B

b. General ranking capturing the pervasiveness of M_A:

M_A » F_A

An examination of the ranking required for Dutch in (2-4) reveals that this is a language-specific instantiation of the general ranking in (5a-b).

3 Anti-structure preservation effects

Imagine that there is some language L_1 like Dutch, in which blocking effects can be observed. From a formal point of view we would say that L_1 has the ranking in (5a-b). Imagine now a second language L_2, in which a blocking effect requires the ranking in (5a), but that in contrast to L_1, there are surface structures in L_2 which violate M_A. From a formal point of view L_2 does not have the ranking in (5b), but instead the one in (6). For reasons to be made

[1] Other FAITH constraints (e.g. MAX-V) and the candidates that violate them have been omitted from the tableaus in (2) and (3) so as not to detract from my goal of illustrating the ranking in (1).

clear below I refer to the situation captured with the ranking in (6) as an ‘anti-structure preservation effect’.

(6) General ranking for anti-structure preservation effects:

$$F_A \gg M_A \gg M_B \gg F_B$$

A hypothetical example of L_2 would be a language like Dutch, with the only difference being that in L_2 there are words like the one in (4) which surface faithfully, i.e. (4a) is the correct output form and not (4c).

The ranking in (6) is referred to as an ‘anti-structure preservation effect’ because the blocking effects which can be observed (in a certain set of words) are contradicted by the existence of ‘anti-structures’ (in a different set of words), where ‘anti-structures’ are defined as those structures prohibited by M_A. Thus, the ranking scheme in (6) (in particular $F_A \gg M_A$) has the function of preserving the anti-structures. The effects of the ranking in (6) are summarized in (7):

(7)

RANKING:	EFFECT:
a. $M_B \gg F_B$:	A process P of the form /Z/ $\rightarrow$ [X] / __ [Q] goes into effect. M_B penalizes [ZQ]. F_B penalizes the change from /Z/ to [X].
b. $M_A \gg M_B$:	A blocking effect: Process P does not go into effect if the output would consist of a sequence of sounds [XY] (or [YX]). M_A penalizes surface sequence [XY] (or [YX]).
c. $F_A \gg M_A$:	An input /XY/ (or /YX/) (the anti-structure) surfaces as [XY] (or [YX]). F_A penalizes any change which prevents /XY/ from surfacing as such.

Put differently, anti-structure preservation effects come about if a language has a regular phonological process which is blocked from applying in a certain set of examples, even though the output would create a sequence of sounds which already exists in the language. It should be noted here that no claim is being made here concerning the number of words which have anti-structures; in some of the examples discussed below there seem to be several dozen, while other examples only appear to have a handful. The important point is that the ranking $F_A \gg M_A$ ensures that these anti-structures surface as such.

It should be emphasized that the existence of anti-structure preservation effects should come as no surprise at all given the OT analysis of blocking effects in (5). Since the OT model predicts that any given ranking can show permutations in other languages it would actually come as a surprise if there were no examples of anti-structure preservation effects.

An important point I make below is that while the OT model captures all anti-structure preservation effects in a unified manner (i.e. as specific instantiations of the general ranking in 6), rule-based approaches cannot do so. Some of the examples discussed in this article can only be captured in a rule-based analysis with *ad hoc*, rule-specific conditions. Other examples require no such stipulations, instead the contrast between [XY] sequences banned by M_A and the [XY] anti-structures are accounted for representationally. The advantage of the present approach is that all examples of anti-structure preservation effects are captured the same way and that no rule-specific conditions nor contrastive phonological representations are necessary.

In the remainder of this section I discuss four sets of examples of anti-structure preservation effects. In §3.1-§3.2 I present examples from German and Gujarati respectively of segmental processes illustrating the necessity of the general ranking in (6). In §3.3-3.4 I show that two languages are attested in which anti-structure preservation effects can be observed with respect to processes involving the formation of glides from the corresponding high vowels, namely German and French. Finally, I show in §3.5 that the 'anti-gemination' effects in Afar (McCarthy 1986) are also a subcase of anti-structure preservation effects. In §4 I conclude.

3.1 German assibilation

In German a /t/ assibilates to [ts] before the palatal glide [j] but the process is consistently blocked after a sibilant. In this section I demonstrate that this is an example of an anti-structure-preservation effect (since German allows for sequences of adjacent sibilants) and that the most insightful analysis of the data requires a specific version of the general constraint ranking in (6). It will also be shown that the present treatment is superior to any conceivable rule-based one because rule-based treatments require an *ad hoc* rule-specific condition to account for the blocking effect after sibilants. The examples below have been drawn from Drosdowski *et al.* (1990) and the analysis has been adapted from Hall (2003a).

The following examples illustrate an alternation between the stop [t] and the affricate [ts]. In the first column we can observe the alternant with the affricate and in the corresponding line of the second column the alternant with [t]. These examples illustrate that the affricate [ts] surfaces consistently before suffixes beginning with the palatal glide [j], namely *–ion*, *–iös*, *–iell*, *–ial*, *–ium*, *–ien* and *–ius*:[2]

(8) Alternations between [t] and [ts] before [j]:

Negation	[negaˈtsjoːn]	'negation'	negativ	[ˈneːgatiːf]	'negative'
infektiös	[ɪnfɛkˈtsjøːs]	'infectious'	Infekt	[ɪnˈfɛkt]	'infection'
existentiell	[ɛksɪstɛnˈtsjɛl]	'existential'	existent	[ɛksɪˈstɛnt]	'existent'
exponential	[ɛksponɛnˈtsjaːl]	'exponential'	Exponent	[ɛkspoˈnɛnt]	'exponent'
Konsortium	[kɔnˈzɔɐtsjʊm]	'syndicate'	Konsorten	[kɔnˈzɔɐtən]	'gang'
Kroatien	[kʀoˈaːtsjən]	'Croatia'	Kroate	[kʀoˈaːtə]	'Croat'
Mauritius	[maʊˈʀiːtsjʊs]	'Mauritius'	mauritisch	[maʊˈʀiːtɪʃ]	'mauritian'

The generalization that can be gleaned from (8) is that /t/ assibilates to [ts] before the palatal glide [j].[3] I analyze this as an operation that alters the value of the feature [strident] (see Hall 2003a, who follows Clements 1999 and Kim 2001 for assibilations in other languages); thus the nonstrident sound /t/ becomes the corresponding affricate [ts] (=[+strident]) before /j/.

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2 In Standard German (see Drosdowski *et al.* 1990) there are said to be two phonetically distinct *j* sounds, namely a glide (sometimes transcribed as [i̯]) and the voiced palatal fricative (=IPA [ʝ]). According to Hall (1992) and Wiese (1996), who both base their analyses on Drosdowski *et al.* (1990), [ʝ] surfaces in absolute syllable-initial position (e.g. *Jahr* [ʝaːɐ] 'year'), and the glide as the second member of an onset cluster (e.g. *Union* [u.ni̯oːn] 'year') and as the second member of the diphthong [aɪ̯], e.g. *Zeit* [tsaɪ̯t] 'time'. In this article I transcribe all '*j* sounds' consistently as [j] because the alleged distinction between [ʝ] and [ɪ̯] is irrelevant.

3 In the literature on German phonology it is usually assumed that the palatal glide in words like the ones in (8) is derived from a short high unrounded vowel by a rule of Glide Formation (see Wurzel 1970, Kloeke 1982, Hall 1992, Yu 1992 and Wiese 1996; see also Trubetzkoy 1939 and Moulton 1962). In the remainder of this section I abstract away from the analysis with /i/ for simplicity and therefore assume that all glides are underlyingly /j/. My assumption concerning the underlying form does not affect my analysis. In §3.3 below I show how [j] derives from /i/ and that this process of glide formation exhibits yet another example of an anti-structure preservation effect.

This analysis follows from the fact that the creation of sibilants from stops has its phonetic origin in the brief period of turbulence which occurs at the release of a stop into the tongue position required for a high vocoid (see Clements 1999 and Kim 2001).

One important point regarding the process of assibilation is that the change from /t/ to [ts] before [j] is not restricted to a derived environment (see Hall 2003a for discussion). Although there are few examples of tautomorphemic /tj/ sequences which could potentially convert to [tsj], many speakers do assibilate in these examples (e.g. recent loanwords like *Patio* and *Pentium* surface as [patsjo] and [pɛntsjʊm] respectively for many speakers). What is more, in nonce words /t/ assibilates to [ts] for many speakers even when there would be no reason for assuming a morpheme boundary between /t/ and /j/, e.g. *fetiolisch*, which can surface as [feˈtsjoːlɪʃ].[4]

The first component of my analysis is the general MARKEDNESS constraint in (9), which penalizes the surface sequence [tj].

(9) MARKEDNESS constraint:
*tj: [tj] is prohibited

The MARKEDNESS constraint in (9) probably has an explanation grounded in perception. For example, Flemming (1995: 120ff.), following earlier work by H. Kawasaki, which I have not seen, argues that the sequence coronal plus palatal glide is marked from a cross-linguistic point of view and that the explanation for the dispreference for such sequences in natural languages is grounded in perception. At present I have no explanation for why /tj/ should be singled out in German from the other coronal plus /j/ sequences, but I assume that there is some kind of explanation grounded in perception.

The MARKEDNESS constraint in (9) conflicts with the FAITH constraint which has the function of preventing /t/ from converting into the affricate [ts]. As noted above, I assume following several authors (e.g. Jakobson *et al.* 1952, LaCharité 1993, Rubach 1994, Clements 1999, Kim 2001, Kehrein 2002) that stops differ from the corresponding affricates in terms of the feature [strident]. Thus, according to this view a stop like /t/ is [–strident] and an affricate like /ts/ is [+strident]. The general FAITH constraint militating against a change in the feature [strident] is presented in (10a). As I argue below, the German facts can only be accounted for if reference is made in the constraint hierarchy for German to the two specific constraints in (10b) and (10c), which refer to the positive and negative values of [strident]. The former one penalizes an intput /t/ that surfaces as [ts] and the latter militates against the change from /ts/ to [t].

(10) FAITH constraints:
a. IDENT (±STRID): If an input segment is [□strident] then the corresponding output segment is [□strident].
b. IDENT (–STRID): If an input segment is [–strident] then the corresponding output segment is [–strident].
c. IDENT (+STRID): If an input segment is [+strident] then the corresponding output segment is [+strident].

[4] Assibilation is regularly blocked across a compound juncture and in personal names (e.g. *Katja* [katja]). See Hall (2003a) for discussion.

The evidence for splitting up the general IDENT constraint in (10a) into the specific constraints referring to the positive and negative values of [strident] is that the latter two occupy different positions in the language-specific constraint hierarchy for German (see below).

Given the language-specific ranking *tj » IDENT (–STRID), an input sequence /tj/ is correctly predicted to assibilate to [tsj]. This point is illustrated in the tableau in (11) for the word *Negation*, which is representative of the general pattern in (8).

(11)

	/negatjoːn/	* tj	IDENT (–STRID)
a.	[negatjoːn]	*!	
b.	☞ [negatsjoːn]		*

In (11) we can see that the assibilation of /t/ to [ts] before [j] is analyzed as a conflict between MARKEDNESS and FAITH. The fully faithful candidate (11a) is not optimal because it violates the high ranking MARKEDNESS constraint banning [tj] sequences. Candidate (11b), although unfaithful to its input, emerges as optimal because it satisfies the MARKEDNESS constraint *tj.

The following words contain a [tj] sequence which is preceded by a sibilant (=[s]).[5] As indicated in the phonetic transcription, no assibilation occurs. Note that the words in (12) contain some of the suffixes in (8) which regularly trigger the general assibilation rule, i.e. *-ion*, *-ial*, *-ium*.

(12) No assibilation after sibilants:

Bastion	[basˈtjoːn]	‘bastion’
Bestie	[ˈbɛstjə]	‘beast’
bestialisch	[bɛsˈtjaːlɪʃ]	‘bestial’
Indigestion	[ɪndigɛsˈtjoːn]	‘indigestion’
Autosuggestion	[ˈaʊtozʊgɛstjoːn]	‘autosuggestion’
Ostium	[ˈɔstjʊm]	‘ostium’

By contrast, assibilation is not blocked if any other consonant precedes, cf. the examples *infektiös, existentiell, Konsortium* in (8). There apparently are no examples of a [tj] sequence which is preceded by a nonsibilant fricative (i.e. [f] or [ç]) or lateral. I assume that these gaps are accidental. Significantly, assibilation in the examples in (12) is blocked even though German allows underlying [sts] sequences. Examples of German words with underlying [sts] are presented in (13). In (13a) we see the [sts] sequence between two vowels and in (13b) between a consonant and a vowel.

(13) Underlying tautomorphemic /sts/ sequences:

a.	Disziplin	[dɪstsiˈpliːn]	‘discipline’
	Faszination	[fastsinaˈtsjoːn]	‘fascination’
	Aszendent	[astsɛnˈdɛnt]	‘ascendant’
	Oszillograph	[ɔstsɪloˈgʀaf]	‘oscillograph’
b.	obszön	[ɔpˈstsøːn]	‘obscene’
	exzentrisch	[ɛkˈstsɛntʀɪʃ]	‘excentic’
	excellent	[ɛkstsɛˈlɛnt]	‘excellent’

5 Apparently the only sibilant which can precede a [tj] sequence in German is [s].

exzessiv	[ɛkstsɛˈsiːf]	‘excessive’
Inszenierung	[ɪnstseˈniːʀʊŋ]	‘production’
transzendental	[tʀanstsɛndɛnˈtaːl]	‘transcedental’

[sts] also occurs word-initially in *Szene* [ˈstseːnə] ‘scene’. Underlying [stsj] sequences are difficult to come by. One example listed in Drosdowski *et al.* (1990) is *Faszie* [fastsjə] ‘fascia, bandage’.

In the analysis that follows I account for the fact that assibilation is blocked from operating after a sibilant even though other words in the language contain adjacent sibilants. The first constraint required is the specific FAITH constraint in (10c), which militates against a change from strident to nonstrident (e.g. /ts/ to [t]). The second component constraint is the MARKEDNESS constraint in (14), which prohibits a sequence of two adjacent sibilants. The same constraint is also posited by Russell (1997: 122) and Gussenhoven & Jacobs (1998) on the basis of English data.

(14) A MARKEDNESS constraint:
*SIBSIB: A sequence of two sibilants is prohibited

The seven sibilants of German are [s z ʃ ʒ ts tʃ dʒ], the only segments in the language I analyze as [CORONAL, +strident]; the one [+strident] sound which is not coronal is the affricate [pf]. I assume that the MARKEDNESS constraint in (14) is OCP-based in the sense that it refers to a sequence of two [CORONAL, +strident] segments.

Given the language-specific ranking in (15), all of the data presented in this section can be accounted for. Here we see that the first two constraints are ranked IDENT (+STRID) » *SIBSIB and the lower two *□[tj » IDENT (–STRID). Recall from (9) that the latter ranking is necessary to account for the change from /t/ to [ts].

(15) IDENT (+STRID) » *SIBSIB » *tj » IDENT (–STRID)

The ranking in (15) – to be illustrated below with specific examples – is a specific instantiation of the general ranking schema in (6) for anti-structure preservation effects.

That *SIBSIB outranks *tj is shown in the tableau in (16) for the word *Bastion*, which is representative of the words in (12).

(16)	/bastjoːn/	IDENT (+STRID)	*SIBSIB	*tj	IDENT (–STRID)
a.	[bastsjoːn]		*!		*
b.	□ [bastjoːn]			*	

In this tableau we can observe that candidate (16b), although violating the otherwise pervasive MARKEDNESS constraint *tj, is better than candidate (16a) because the latter form is not in line with the higher ranking MARKEDNESS constraint *SIBSIB. What this means is that /t/ assibilates to [ts] unless the /t/ is preceded by a sibilant, in which case it surfaces as [t].

The reason for the ranking IDENT (+STRID) » *SIBSIB can be seen when we consider the following tableau for *Disziplin*, which is representative of the data in (13). Here it is illustrated that this ranking is necessary to allow for underlying [sts] sequences – the anti-structures – to surface as such:

(17)

[dɪstsipliːn]	IDENT (+STRID)	*SIBSIB	*tj	IDENT (–STRID)
a. [dɪstipliːn]	*!			
b. ☞ [dɪstsipliːn]		*		

In this tableau the nonoptimal candidate (17a), although satisfying both MARKEDNESS constraints, loses out to (17b) because the change from /ts/ to [t] violates the high ranking FAITH constraint IDENT (+STRID).[6]

It should be emphasized that it would be difficult for a rule-based analysis to account for the nonassibilation of /t/ in the examples in (12) without unmotivated stipulations. One possible treatment would require an assibilation rule of the form /t/ → [ts] / __ j and a negative filter barring adjacent sibilants (to explain the data in 12). One would consequently have to situate both the rule and the filter at the same stratum in the lexicon to capture the fact that the rule is blocked when the output violates the filter. The problem with this analysis is that it cannot account for the existence of words like *Disziplin* in (13), since they would also be ruled out by the filter. One might alternatively argue, contrary to what was stated above, that assibilation is a true derived environment rule, in which case its application would be blocked in (13) because these are nonderived words. This analysis is weak because it cannot capture the fact that there is no assibilation in (13) for a *phonological* reason, namely because an /s/ precedes /t/.

In terms of rule-based phonology the only analysis which might work technically is one which encodes a rule-specific condition into assibilation. In this case the condition would simply say that this particular rule does not apply if the target is preceded by a sibilant, and since this condition is a part of the rule itself, it would not have the power to filter out the words in (13). While this analysis might work technically it requires a stipulation in the structural description of a rule. By contrast, the OT analysis presented above has the advantage that it requires no rule-specific condition and that all facts presented above are captured with the interaction of four universal constraints, namely the two FAITH constraints posited in (10b-c), which penalize outputs which change the underlying value of stridency and two MARKEDNESS constraints.[7]

1.2 Sibilant neutralization in Gujarati

In the historical development from Sanskrit to Gujarati we can observe a general process which neutralized nonanterior sibilants to [s]. It will be shown below that this process is an example of an anti-structure-preservation effect which is captured with a specific version of the general ranking in (6). The data in this section are drawn from Pandit (1954). An earlier rule-based analysis is presented in Hall (1996).

Sanskrit had three sibilant phonemes presented in the first column in (16) with the traditional symbols which I use below. In the second column I list the corresponding IPA symbols and in the third column the corresponding features.

6 Recall from (6) that M_A (=*SIBSIB in 17) is dominated by F_A, i.e. all other FAITH constraints militating against the sequence banned by M_A. In the present case two additional examples of F_A are DEP-IO and MAX-IO. The ranking DEP-IO, MAX-IO » *SIBSIB accounts for the fact that the anti-structure input sequence /sts/ surfaces as [sts] and not as [səts] (DEP-IO violation) or [ts] (MAX-IO violation).

7 See McCarthy (1997), who analyzes a rule-specific condition in the Southern Palestinian dialect of Arabic in an OT analysis. However, McCarthy's OT analysis does not require the same kind of interaction between FAITH and MARKEDNESS constraints as my own.

(18)	*Symbol:*	*IPA Symbol*	*Features:*
	s	s	[CORONAL, +anterior]
	ś	ʃ or ç	[CORONAL, –anterior, +distributed]
	s̥	ʂ	[CORONAL, –anterior, –distributed]

I assume that as the only anterior sibilant, [s] is not marked for [distributed], but nothing in my analysis crucially hinges on this.

The two nonanaterior sibilants in (18) neutralized to [s] in most Middle Indo-Aryan dialects (Pandit 1954; Misra 1967: 124-126; Masica 1991: 168). In the Gujarati examples in (19) we can also observe the effects of this general process of sibilant neutralization. In the first four examples the nonanaterior sibilant was [ś] and in the final one it was [s̥]:

(19) *Sanskrit*	*Gujarati*	
śat̥ati	sar̥vũ	'to rot'
śun̥d̥ā	sũd̥lo	'basket'
ādarśah̥	ārso	'mirror'
śvāsah̥	sās	'breath'
mās̥a	māso	'measure of weight'

The change from Sanskrit [ś s̥] to Gujarati [s] can be seen as the result of a conflict between the MARKEDNESS constraint in (20) which penalizes nonanterior sibilants and a FAITH constraint which had the function of preventing the change from [–anterior] to [+anterior]. The former constraint is presented in (20):

(20) A MARKEDNESS constraint:
*NONANTSIB: No nonanterior sibilants (i.e. *[CORONAL, –anterior, –strident])

The constraint *NONANTSIB is motivated by typological evidence. since the unmarked sibilant inventory contains /s/ (as opposed to /s/ and a nonanterior sibilant like /ʃ/) (see Maddieson 1984).

The general FAITH constraint referring to both values of [anterior] is presented in (21a) and the specific one required for the data in (19) in (21b).

(21) FAITH constraints:
a. IDENT(±ANT): an input segment is [αanterior] then the corresponding ou
segment is [αanterior].
b. IDENT(–ANT): an input segment is [–anterior] then the
segment is [–anterior].
c. IDENT(+ANT): an input segment is [+anterior] then the
segment is [+anterior].

In (22) I show by way of the hypothetical example /śa/ how this form surfaces as [sa] in Gujarati. In (22) and below the input is taken to be the acoustic input from Sanskrit and the output forms are the ones which surface in Gujarati.

(22)	/ śa/	*NONANTSIB	IDENT(–ANT):
a.	[śa]	*!	
b.	☞ [sa]		*

In this tableau it can be observed that the correct form in (22b) is better than the fully faithful one in (22a) because the latter form violates the high ranked MARKEDNESS constraint which penalizes nonanaterior sounds.

In all of the examples in (19) sibilant neutralization takes place before a back vowel. The additional data in (23) illustrate that the neutralization of [ś] to [s] did not take place before front vowels but that in this context Sanskrit [ś] stays [ś] in Gujarati.[8]

(23) *Sanskrit*	*Gujarati*	
śiks̥ā	śīkh	'advice'
śītakālah	śiyāl̥o	'winter'
śīrs̥am	śīś	'head'

What the examples in (23) show is that the neutralization of nonanterior sibilants to [s] is suspended before front vocoids; thus, Sanskrit did not allow sequences like [si] and [se] to arise by way of sibilant neutralization. I capture this generalization with the sequential MARKEDNESS constraint in (24), which penalizes a sequence of anterior sibilant plus front vocoid:

(24) A MARKEDNESS constraint:
*si: No sequence of anterior sibilant plus front vocoid.

If the constraint *si is ranked ahead of the MARKEDNESS constraint *[COR, –ANT] then the correct output for the data in (23) is obtained. This is illustrated in the tableau in (25):

(25)	/śi/	IDENT (+ANT)	*si	*NONANTSIB	IDENT (–ANT)
a.	[si]		*!		*
b.	☞ [śi]			*	

In (25) we can observe that an input /śi/ surfaces optimally as [śi] and not as [si] because only the former form satisfies the high ranked MARKEDNESS constraint *si.

The additional examples in (26) illustrate that Sanskrit [s] surfaces as [s] in Gujarati, even if a front vocoid follows:

(26) *Sanskrit*	*Gujarati*	
samvarate	sāvarn̥ī	'broom stick'
sinduram	sindur	'red lead powder'
sedbati	sidhāvvũ	'to depart'
vāsita	vāsī	'stale'

The significance of the examples in (26) is that they show that Gujarati allows for [si] sequences only if these [si] sequences had /si/ as the input and not /śi/.

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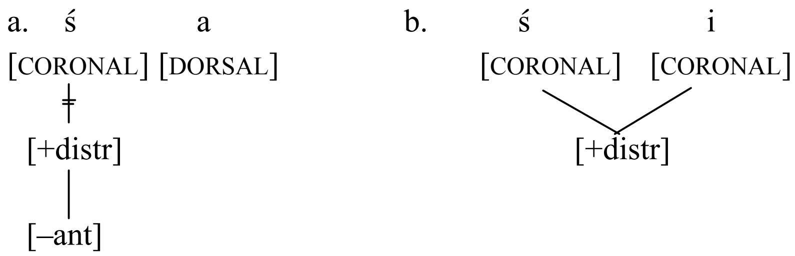
8 Pandit (1954) shows that Sanskrit [s̥] surfaced in Gujarati as [ś] before a front vowel or front glide. I ignore these examples here because they require an added complication (namely the markedness constraint *s̥i) which is peripheral to the present discussion.

That an original [s] surfaces in Gujarati as [s] falls out from the rankings presented in (25) above with the addition of the FAITH constraint in (21c), which penalizes the change from [+anterior] to [–anterior]. If this IDENT constraint occupies the highest niche in the constraint hierarchy for Gujarati then the present analysis correctly predicts that input /si/ – the anti-structure – will consistently map onto surface [si]:

(27)

	/si/	IDENT (+ANT)	*si	*NONANTSIB	IDENT (–ANT)
a.	[śi]	*!		*	
b.	☞ [si]		*		

In contrast to the example discussed in §3.1, it is possible to account for the Gujarati facts in a rule-based model (see Hall 1996, whose analysis I summarize here). Assuming that the feature [distr] is a daughter of [CORONAL] and that [ant] in turn is dominated by [distr] the change from /śa/ to [sa] can be expressed as the delinking of a line of association, as in (28a). (The [s] that results from this operation receives the feature [+anterior] by default). If a sequence like [śi] shares the feature [+distr] (see 28b), then the blockage of sibilant neutralization to this structure follows from representational accounts for the inalterability of linked structures (e.g. Hayes 1986).

(28)


Although the analysis in (28) works technically I claim that the true explanation for the rule blockage in [śi] is due to constraint rankings and not nonlinear representations. The reason I adopt the constraint ranking approach is that the same kind of anti-structure preservation effects can be observed in other languages, in which a possible analysis in terms of nonlinear representations is not possible even in theory (e.g. German assibilation in §3.1 and German glide formation in §3.3).[9]

1.3 German glide formation

Following earlier work on German phonology (recall note 3), I hold that [j] in that language derives from an underlying vowel /i/ because [i] and [j] stand in complementary distribution (see Wurzel 1970, Kloeke 1982, Hall 1992, Yu 1992 and Wiese 1996; see also Trubetzkoy 1939 and Moulton 1962, who make a similar assumption in pre-generative frameworks).[10] It will be argued that German glide formation provides a clear example of an anti-structure-preservation effect because the process is blocked from going into effect if the output would be [ji], even though the language as a whole allows for [ji] sequences.

The examples in (29) illustrate that [j] surfaces in onset position, i.e. either in absolute syllable-initial position (in 29a), or as the second member of an onset cluster (in 29b). By

[9] This does not mean that one should reject nonlinear rperesentations like the ones in (28) altogether; the point is that an explanation for the Gujarati examples does not *require* nonlinear representations.

[10] Hall (1992) and Wiese (1996) argue that [j] is derived from /ɪ/ (and not /i/). The difference between the two analyses is very subtle and does not affect the analysis presented above.

contrast, (unstressed) [i] (or its allophone [iː], which surfaces in stressed position) only occurs in the nucleus.

(29) The distribution of German [j]:

a.	Jahr	[jaːɐ]	'year'
	Boje	[boːjə]	'buoy'
b.	prinzipiell	[pʀɪn.tsi.pjɛl]	'in principle'
	Nation	[na.tsjon]	'nation'
	Studium	[ʃtuː.djʊm]	'studies (sg.)'

Evidence that the Cj sequences in (29b) are parsed as V.CjV and not as VC.jV is that the C portion does not undergo (syllable) Final Devoicing if it is a voiced obstruent. See Hall (2003a) for discussion and an OT analysis of the syllabification of Cj sequences.

Following earlier work by Rosenthall (1994) on glide formation in OT, I hold that the phonetic forms in (29) falls out from the interaction between ONSET (see 30a) and MAX-μ (see 30b).The language-specific ranking is presented in (30c):

(30) a. A MARKEDNESS constraint:
ONSET: Syllables are not vowel initial
b. Two FAITH constraints:
MAX-μ: A mora in the input corresonds to a mora in the output.
DEP-μ: A mora in the output corresonds to a mora in the input.
c. ONSET » MAX-μ

The constraint MAX-μ militates against the change from a vowel (i.e. /i/) to a glide (i.e. [j]). Thus, if the moraic segment /i/ becomes the (nonmoraic) [j] then what is involved is the deletion of an underlying mora in order to satisfy ONSET. The tableau in (31) shows how the optimal form with a glide is selected for the word *Studium*, which is representative of the words in (30):

(31)

	/ʃtuː.diʊm/	ONSET	MAX-μ
a.	[ʃtuː.di.ʊm]	*!	
b.	☞ [ʃtuː.djʊm]		*

In this tableau we can observe that the nonoptimal candidate (31a) loses out to the winner in (31b) because it violates the highest ranked constraint ONSET.[11]

The following data show that glide formation as in (29) is blocked when [iː] follows. This point is illustrated in the first column of (32), in which the root ends in [i] and the suffix begins with [iː]. An examination of the examples in the second column reveals that the root-final [i] in the corresonding morphemes in the first column surfaces as [j] if a vowel other than [iː] follows.[12] For clarity morpheme boundaries in (32) have been indicated in the

[11] German permits ONSET violations in words with vowels in hiatus in which the first vowel is not /i/, e.g. *naiv* [na.iːf] 'naive'. I assume here that a form like [na.iːf] is selected as optimal due to other constraints which are not relevant for the present analysis. See Rosenthall (1994) for discussion of this issue with respect to languages other than German.

[12] The examples in (32) have been drawn from Drosdowski *et al.* (1990). Some informants can pronounce the [j] in the words in the second column as [j] or as [i], suggesting the glide formation in certain words is optional, e.g. [ˈliːnjə] or [ˈliːniə]. Importantly, there is no optionality regarding the pronunciation of [iiː] in the words in the first column in (32), i.e. all informants categorically reject the pronunciation [jiː].

orthographic form with a dash. There are no suffixes beginning with a vowel other than [iː] which could attach to the root in the final form in (32).

(32) No glide formation before [iː]:

lini-ieren	[liniˈiːʀən]	'rule'	Lini-e	[ˈliːnjə]	'line'
Alli-ierten	[aliˈiːɐtən]	'allies'	Alli-anz	[aˈljants]	'alliance'
Initi-ierung	[initsiˈiːʀʊŋ]	'initiation'	initi-al	[iniˈtsjaːl]	'initial'
vari-ieren	[vaʀiˈiːʀən]	'vary'	Vari-etät	[vaʀjeˈtɛːt]	'variety'
assozi-ieren	[asotsiˈiːʀən]	'associate'	assozi-ativ	[asotsjaˈtif]	'associative'
substanti-ieren	[zʊpstantsiˈiːʀən]	'substantiate'	substanti-ell	[zʊpstanˈtsjɛl]	'substantial'
li-iert	[liˈiːɐt]	'be on intimate terms with someone'			

The only tautomorphemic [iiː] sequences to my knowledge occurs in the word *Schiit* [ʃiiːt] 'Shiite'. As in the examples in (32), no glide formation occurs in this word.

I argue that the blockage of glide formation in the examples in the first column of (32) falls out from the MARKEDNESS constraint in (33), which, as I demonstrate below, must be ranked ahead of ONSET:

(33) A MARKEDNESS constraint:
*ji

The OCP motivated constraint in (33) has been proposed by several linguists (e.g. Kawasaki 1982, which I have not seen) and has been argued to be motivated by speech perception.[13]

The ranking *ji » ONSET is illustrated in the following tableau for the word *liniieren*, which is representative of the words in the first column of (32):

(34)

	/lini-iːʀən/	*ji	ONSET	MAX-□
a.	☞ [li.ni.iː.ʀən]		*	
b.	[li.njiː.ʀən]	*!		*

In this tableau it can be observed that the incorrect form in (34b) violates the high ranked constraint *ji and therefore loses out to the form in (34a).

The following words illustrate that German permits the anti-structure (i.e. [ji] sequences) on the surface:

(35)

injizieren	[ɪnjiˈtsiːʀən]	'inject'
projizieren	[pʀojiˈtsiːʀən]	'project'
konjizieren	[kɔnjiˈtsiːʀən]	'conjecture'

There are no German words beginning with /ji/, but this sequence is not difficult to pronounce (either in word-initial position or word-internally) and therefore there is no tendency at all to repair /ji/ sequences from other languages when they enter German as loanwords, e.g. Czech *Jičin*, German [jitʃiːn]. Note that the /j/ in the words in (35) must be analyzed as underlyingly

A glottal stop surfaces before the stressed vowel in words like *liniieren* in (32) – an epenthesis that is motivated to avoid an ONSET violation, as in Dutch (recall the example in 2, which is the same as in German).

13 The [ji] gap in other languages is sometimes assumed to be attributed to the OCP if /j/ has the same features as /i/. This treatment will not work for the German examples because sequences of two /i/'s are grammatical (recall the first column in 30).

/j/ and not /i/. The underlying glide is necessary here because there are word pairs in which [i] and [j] contrast, e.g. [ɪnjiˈtsiːʀən] 'inject' vs. [liniˈiːʀən] 'rule' in which [i] and [j] occur in the context C__i.

That the [ji] sequences in (35) are the optimal forms (as opposed to ones containing [ii]) falls out given the ranking of the three constraints in (34) and the Faith constraint Dep-μ (from 30b), which prohibits the insertion of a mora. That Dep-μ outranks *ji is illustrated in the tableau in (36) for the word *injizieren*, which is representative of words containing an underlying /ji/.

(36)

	/ɪnjitsiːʀən/	Dep-μ	*ji	Onset	Max-μ
a.	☞ [ɪn.ji.tsiː.ʀən]		*		
b.	[ɪ.ni.i.tsiː.ʀən]	*!		*	

It can be observed in (36) that the constraint Dep-μ plays a crucial role in my analysis by preventing the form in (36b) from being selected as optimal.

The complete ranking for German is presented in (37):

(37) Dep-μ » *ji » Onset » Max-μ

Note that this specific ranking matches the general ranking presented in (6) above for anti-structure preservation effects. What crucially differentiates the ranking in (37) from the kind of blocking effects as described in §2 is the partial ranking Dep-μ » *ji, which ensures that the anti-structure (i.e. /ji/) surfaces faithfully.

Note that my analysis crucially requires that vowels be underlyingly moraic and that glide formation in (29) (and the data in 32) be captured with the faith constraints Max-μ and Dep-μ. An alternative analysis of glide formation, which I reject below, analyzes the change from /i/ to [j] (and from /j/ to [i]) by constraints penalizing [i] if it occurs as a peak or a margin (i.e. *P/i and *M/i respectively; see Prince & Smolensky 1993 and Baertsch 2002). According to this approach one could analyze glide formation (i.e. the change from /i/ to [j] before a vowel) by ranking Onset over *M/i, as in (38).

(38)

	/ʃtuː.diʊm/	Onset	*M/i
a.	[ʃtuː.di.ʊm]	*!	
b.	☞ [ʃtuː.djʊm]		*

The reason one cannot substitute Max-μ and Dep-μ with *M/i and *P/i respectively is that no ranking between these constraints will select the correct winner for the *liniieren* and *injizieren* examples, as illustrated in (39) and (40):

(39)

	/lini-iːʀən/	*P/i	*ji	Onset	*M/i
a.	[li.ni.iː.ʀən]	***!		*	
b.	☞ [li.njiː.ʀən]	**	*		*

(40)

	/ɪnjitsiːʀən/	*P/i	*ji	Onset	*M/i
a.	☞ [ɪn.ji.tsiː.ʀən]	**	*		
b.	[ɪ.ni.i.tsiː.ʀən]	***!		*	

Although the correct output form is selected in (40), in (39) we can observe that (39b) is incorrectly selected as optimal (symbolized above as '□ ').

In conclusion, it needs to be stressed that any rule-based analysis will not be able to account for all of the German data presented above without *ad hoc* stipulations. In order to account for glide formation a rule would need to be posited of the form /i/ □ [j] / __ V. In order to account for the blockage of this process before [i] a filter would be necessary of the form *ji, but it remains unclear how the examples in (32) can be made exempt from the filter. By contrast, the OT analysis presented above accounts for the anti-structure preservation effect with a simple ranking involving four universal constraints.

1.4 French glide formation

In French there is a process of glide formation which converts the high vowels /i u y/ into the corresponding glides [j w ɥ] in pre-vocalic position. This rule has been discussed extensively by a number of authors (e.g. Kaye & Lowenstamm 1984, Tranel 1987: 115ff., Kaye 1989: 112ff., Noske 1993: 221ff., Rialland 1994), primarily from the perspective of nonlinear representations. The French glide formation data provide two clear examples of anti-structure-preservation effects. First, the general rule of glide formation is blocked if it is preceded by a consonant+liquid (CL) cluster, but there are other words in the language which have consonant-liquid-glide sequences in the onset (see §3.4.1). In the second case (described by Tranel 1987) glide formation is blocked for many speakers after /r/, even though for these speakers there are other words which contain [rj] sequences (see §3.4.2).

1.4.1 Glide formation blocked by preceding CL clusters

The process of glide formation is illustrated with the data in (41) (from Tranel 1987). In the first column I have listed words ending in one of the three high vowels [i u y]. In the second column we can observe that these high vowels surface as the corresponding glides [j w ɥ] before vowel-initial suffixes.

(41) French glide formation (Tranel 1987: 119):

scie	[si]	'saw'	scier	[sje]	'to saw'
défi	[defi]	'challenge'	défier	[defje]	'to challenge'
tue	[ty]	'kills'	tuer	[tɥe]	'to kill'
mue	[my]	'shedding'	mue	[mɥe]	'to shed'
secoue	[sœku]	'shakes'	secouer	[sœkwe]	'to shake'
loue	[lu]	'rents'	louer	[lwe]	'to rent'

Additional data (from Noske 1993: 222) suggest that the process of glide formation is not restricted to a derived environment, but instead that it affects any pre-vocalic high vowel e.g. *nuage* [nɥaʒ] 'cloud' (from /nyaʒ/).[14]

I capture glide formation in French with the ranking ONSET » MAX-□ (recall the analysis in §3 for German). This ranking is ilustrated with the tableau in (42) for the word [lwe]:

---

[14] Noske (1993) and Rialland (1994) describe glide formation as an optional process. For example, the latter author lists [nwe] and [nue] as possible pronunciations for the word *nouer* 'to tie' (p. 137). The analysis I present below is not intended to capture the optionality of glide formation, since this is an independent issue. Glide formation is systematically blocked from applying to a high vowel in three contexts (see Tranel 1987: 119): (i) across a prefix+stem juncture, (ii) across a compound juncture, and (iii) across words. See Hannahs (1995) for an analysis of French glide formation in which the contexts in (i)-(iii) are discussed. In my analysis I assume that the restrictions fall out from various ALIGN constraints.

(42)

/lu-e/	ONSET	Max-μ
a. [lu.e]	*!	
b. ☞ [lwe]		*

In this tableau we can see that the faithful candidate in (42a) is not optimal because it violates the high ranking constraint ONSET.

The data in (43) illustrate that glide formation is blocked after a consonant + liquid (henceforth CL) cluster. This is illustrated in the second column, where it can be observed that the stem-final high vowel does not surface as the corresponding glide:[15]

(43) Glide formation blocked after CL clusters (Tranel 1987: 120):

plie	[pli]	‘fold’	plier	[plije]	‘to fold’
ennui	[ɑ̃nɥi]	‘boredom’	ennuyer	[ɑ̃nɥije]	‘to bore’
glu	[gly]	‘birdlime’	gluant	[glyɑ̃]	‘sticky’
clou	[klu]	‘nail’	clouer	[klue]	‘to nail’

Rialland (1994: 138) presents examples of words in which glide formation occurs after word-initial CC sequences, where the C’s are both obstruents, e.g. *skier* [skje] ‘to ski’ (from /skie/), and in less frequent words, e.g. *psiadie* [psjadi] ‘psiadie’ (from /psiadi/). These additional examples are important because they tell us that glide formation is blocked after CL clusters and not after any CC sequence.

The blockage of glide formation in (43) can be understood in terms of the MARKEDNESS constraint in (44), which bans syllables beginning with three segments. I assume that *$_\sigma$[CCC is a specific instantiation of the constraint NOCOMPLEXONSET (Prince & Smolensky 1993).

(44) A MARKEDNESS constraint:
*$_\sigma$[CCC: No syllable begins with a sequence of three nonsyllabic segments.

If the constraint *$_\sigma$[CCC outranks ONSET then the correct prediction is made that glide formation is blocked in the examples in (43). This point is illustrated in the tableau in (45) for the word [klue]:

(45)

/klu-e/	*$_\sigma$[CCC	ONSET	Max-μ
a. ☞ [klu.e]		*	
b. [klwe]	*!		*

In this tableau we can see that the optimal form is (45a), since the sequence CCj in (45b) violates the high ranked MARKEDNESS constraint *$_\sigma$[CCC.[16]

[15] In French phonology it is usually assumed that there is a palatal glide between the [i] and following vowel, e.g. [plije] and not [plie]. By contrast, no glide is posited after [u ɥ]. I leave open here what a formal analysis of why examples like [plije] are better than ones like [plie] would look like. One also might want to consider analyzing the palatal glide in the context i__V to be purely the consequence of coarticulation or perception and that it should not be accounted for in a phonological analysis.

[16] The analysis in (45) brings up the question of how glide formation can be applied successfully after word-initial CC clusters, e.g. *skier* [skje] ‘skier’ (recall the discussion after 43). Surface forms like [skje] can be selected as optimal by either positing that the first of two word-initial obstruents is extrasyllabic (see Rialland 1994 who defends this option), or by conjoining the constraint *$_\sigma$[CCC with one that bans liquids in the

My analysis in (45) is very different from the one that is traditionally assumed in French phonology (see the references cited above). According to that view glide formation is blocked in examples like (43) because if it were to apply then there would be a sequence of three consonants within the subsyllabic constituent onset, which is said to be banned by an exceptionless constraint. By contrast, in my treatment the constraint $*_{\square}$[CCC does not crucially require the subsyllabic constituent onset, but instead it refers simply to a sequence of three nonsyllabic segments situated in syllable-initial position. A second difference between the traditional analysis and my own is that my constraint $*_{\square}$[CCC is violable. This point is illustrated when we consider the examples in (46), which contain the anti-structures (i.e. underlying $*_{\square}$[CCG sequences). Note that the glide in these examples contrasts with the corresponding high vowel (cf. 47). In the literature on French phonology it is assumed that the glide in these words is situated in the nucleus (and not in the onset) and that this is the explanation for why these examples do not violate the filter referred to above which bans a CL sequence in the subsyllabic constituent onset.

(46) Underlying CLw and CLɥ sequences (Tranel 1987: 116):

a.	trois	[trwɑ]	‘three’
	cloison	[klwazõ]	‘partition’
b.	bruit	[brɥi]	‘noise’
	fluide	[flɥid]	‘fluid’

(47) Underlying CLu and CLy (Tranel 1987: 116)

a.	clouer	[klue]	‘to nail’
	prouesse	[pruɛs]	‘prowess’
b.	cruauté	[kryote]	‘cruelty’
	fluet	[flyɛ]	‘slim’

Apparently there are no examples of French words like the ones in (46), in which the glide portion of the onset is [j].

In the present analysis the examples in (46) and (47) can be captured by ranking the FAITH constraint DEP-□ ahead of $*_{\square}$[CCC. This ranking is illustrated in the two tableaux in (48) and (49) for [trwɑ] and [klue] respectively.

(48)

	/ trwɑ/	DEP-□	$*_{\square}$[CCC	ONSET	MAX-□
a.	[tru.ɑ]	*!		*	
b.	□ [trwɑ]		*		

(49)

	/ klue /	DEP-□	$*_{\square}$[CCC	ONSET	MAX-□
a.	[klwe]		*!		*
b.	□ [klu.e]			*	

In (48) we see that the incorrect form in (48a) loses out to the winner because the change from /w/ to [u] is disallowed by the high ranking constraint DEP-□. In the second tableau the form in (49b) surfaces as optimal even though this form exhibits an ONSET violation because the

onset. Since my analysis of the French facts as anti-structure preservation effects does not crucially hinge on either option I leave this question open for further study.

change from /u/ to [w] in (49a) violates the higher ranked MARKEDNESS constraint *□[CCC.[17] [18]

1.1.2 Glide formation blocked by preceding /r/

Tranel (1987: 121) presents some additional data involving glide formation in French which I see as another example of an anti-structure preservation effect in that language. Tranel notes that in French the vowel [i] rarely turns into the corresponding glide [j] after the rhotic [r].[19] Illustrating this point with the verb *rire* 'to laugh', he notes that the pronunciations in (50a) are much more common than the ones which glide formation has applied (e.g. [rjɑ̃]). He writes "...while no speaker will find the first set impossible (e.g. [rijɑ̃], T. A. H.), many speakers will find the second set (e.g. [rjɑ̃], T. A. H.) odd". Interestingly, Tranel adds that [rj] sequences in nonderived words are possible, citing the place name *Riom* in (50b) as an example. The data in (50a) contrast with the ones in (50c), in which [l] precedes the high vocoid (these examples consist of derivatives of the verb *lier* 'to link'). Tranel notes that in contrast to the examples in (50a) in (50c) it is the pronunciations with [lj] which are "probably more generally accepted than the first (i.e. [li], T. A. H.)."

(50) Li and Lj sequences in French (Tranel 1987: 121)

a.	[rijɑ̃]	'cheerful'
	[rijœr]	'merry'
	[rijõ]	'(we) laugh'
b.	[rjõ]	'Riom'
c.	[ljɑ̃]	'sociable'
	[ljœr]	'binder'
	[ljõ]	'(we) link'

Tranel concludes that "the consonant [l] more readily accepts gliding next to it than does the consonant [r]."

I account for the blockage of glide formation in (50a) with the sonority-based MARKEDNESS constraint in (51) (from Hall 2003b):

(51) A MARKEDNESS constraint:
*rj

The constraint in (51) penalizes a sequence of rhotic (regardless of manner and/or place) plus palatal glide. Hall (2000, 2003b) shows that the constraint *rj derives motivation (when the /r/ is coronal) from articulatory phonetics in the sense that it would require a tongue tip plus concave tongue posture be altered to a blade plus convex posture. Hall (2000, 2003b) also notes that a phonetic (i.e. articulatory) explanation for (51) holds when /r/ is uvular as well,

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[17] Recall that there are no examples of words like the ones in (46) in which the glide is [j]. What this suggests is that only the blocking effects which involve a change from /u y/ to [w ɥ] are anti-structure preservation effects, whereas the blockage of /i/ to [j] in the first two examples in (43) display blocking effects.

[18] One question I have not addressed in my analysis of French is how glides are represented phonologically. As I noted above the general assumption in the literature is that the glide in words like [trwa] (in 46) are in the nucleus, whereas the same segment in words like [lwe] (in 41) is in the onset. In my treatment the distinction between onset glides and nuclear glides is not important, and hence both sounds could, in principle, be represented the same way.

[19] The place of articulation for French /r/ is uvular (see Tranel 1987: 142ff., who refers to French /r/ as 'back'). The manner of articulation varies from a trill to a tap.

since it is difficult to move the tongue from the position required for a uvular constriction to [j]. (This derives support from the extreme rarity from the cross-linguistic perspective of palatalized uvular sounds).

The data in (50) require the ranking in (52), a specific instantiation of the general constraint schema in (5) for anti-structure preservation effects:

(52) DEP-□ » *rj » ONSET » MAX-□

The ranking in (52) differs minimally from the one posited above in (48-49) for the additional French data and for the German data in §3.3.

The ranking in (52) is illustrated in the following three tableaus for the words [.ljõ.] (from 50c), [.ri.ã.] (from 50a) and [.rjõ.] (the anti-structure, from 50b).

(53)	/li+õ/	DEP-□	*rj	ONSET	Max-□
a.	[.li.õ.]			*!	
b.	☞ [.ljõ.]				*

(54)	/ri+ã/	DEP-□	*rj	ONSET	Max-□
a.	☞ [.ri.ã.]			*	
b.	[.rjã.]		*!		*

(55)	/rjõ/	DEP-□	*rj	ONSET	Max-□
a.	[.ri.õ]	*!		*	
b.	☞ [.rjõ.]		*		

The general glide formation example is represented by tableau (53). As in (42) glide formation in (53) is captured with the ranking ONSET » MAX-□. The blockage of glide formation after a rhotic is illustrated in (54). Here we can observe that (54b) is not optimal because it violates the high ranked MARKEDNESS constraint *rj. The final tableau shows that the antistructures (i.e. underlying /rj/ sequences) surface as such and that the faithful candidate wins due to the ranking DEP-□ » *rj.

1.5 'Anti-gemination' effects in Afar

An excellent example of an anti-structure preservation effect is the phenomenon referred to as 'anti-gemination' in the Lowland East Cushitic language Afar (McCarthy 1986). We will see below that vowel syncope in this language is blocked if it would create a geminate but that this language has underlying tautomorphemic and heteromorphemic geminates.

In Afar (described by Bliese 1981: 214-217, and analyzed by McCarthy 1986 in a rule-based approach) there is a rule of syncope that deletes an unstressed vowel in a peninitial two-sided open syllable. The effects of this process can be observed in the Afar words in the second column of (55). A comparison of these forms with the corresponding ones in the first column reveal that there are vowel-zero alternations.

(55) Afar Syncope (Bliese 1981: 215):

[digib-ˈt-e]	'she married'	[digˈb-e]	'I married'
[wager-ˈn-e]	'we reconciled'	[wagˈr-e]	'he reconciled'
[xawal-ˈt-e]	'she tired'	[xawˈlele]	'she will tire'

Following Rose (2000: 134), I employ the informal constraint DELETE, which penalizes fully faithful forms without deletion. I assume that DELETE is a MARKEDNESS constraint which penalizes forms which are metrically nonoptimal (see Zawaydeh 1997, who assumes that it involves a ban on adjacent light open syllables). Given the ranking DELETE » MAX-V (proposed by Rose 2000) my analysis correctly selects the syncopated candidate:

(56)	/digib-e/	DELETE	Max-V
a.	[digibe]	*!	
b.	☞ [digbe]		*

The following examples illustrate that syncope is blocked from going into effect if the consonants flanking the unstressed vowel are identical. This example of rule blockage is referred to as anti-gemination in the literature because the output of syncope is blocked if it would be a geminate consonant.

(57) Anti-gemination effects (Bliese 1981: 215):

[danaˈn-e]	‘I/he was hurt’
[xaraˈr-e]	‘I/he burned’
[modoˈd-e]	‘I/he collected animals to bring home’

In my analysis (which follows closely the one proposed by Rose 2000: 104-105) the blockage of syncope in (57) is the predicted result if the constraint DELETE in (56) is dominated by a MARKEDNESS constraint banning geminate consonants (i.e. NOGEM). This ranking is illustrated in the following tableau for the first example in (57):

(58)	/danan-e/	NOGEM	DELETE	Max-V
a.	[danne]	*!		*
b.	☞ [danane]		*	

The constraint NOGEM is only violated by ‘true’ geminates, i.e. geminates with a single root node. The form in (58a) violates this constraint because [nn] is understood to be such a geminate.[20] Given the ranking NOGEM » DELETE the correct form in (58) is correctly predicted to be the one without deletion, i.e. (58b).

As pointed out by McCarthy (1986: 221) (who attributes this observation to Bliese 1981: 215) the condition on rule blockage described above is rather unexpected because Afar otherwise shows no aversion to geminate consonants (which would surface if syncope would apply in 57). Thus, Afar has both tautomorphemic and heteromorphemic geminates in underlying and surface representations, e.g. [yalˈli-h] ‘God-gen’ (Bliese 1981: 212; [y] = IPA [j]). In the present analysis the underlying tautomorphemic geminates are the anti-structures which surface as such because the MARKEDNESS constraint NOGEM is domainted by the FAITH constraint which militates against the structure banned by that MARKEDNESS constraint, i.e. geminates.

Following Keer (1998), I assume that input (tautomorphemic) geminates always consist of a single segment (i.e. root node). Given this assumption concerning the input the

[20] There is also a candidate [danne] (not seen in 58) with a ‘fake’ geminate, i.e. [nn] is represented with two separate identical segments. This form is ruled out if the constraint OCP (which it violates) dominates DELETE. Rose (2000: 104) assumes without argument the reverse ranking but nothing in her analysis would be affected by this proposed ranking.

only FAITH constraint violated by the simplification of a tautomorphemic geminate is MAX-CONS-μ. (I am assuming that the first part of a tautomorphemic geminate is underlyingly moraic; the constraint only penalizes a consonantal mora for reasons to be described below). Underlying geminates are now correctly predicted to surface as such if the MARKEDNESS constraint NOGEM is dominated by the FAITH constraint MAX-CONS-μ. This ranking is illustrated in the following tableau for the word /yalli-h/ 'God-gen':

(59)	/yalli-h/	MAX-CONS-μ	NOGEM	DELETE	Max-V
a.	[ya.lih]	*!			
b.	☞ [yal.lih]		*		

In this tableau we can observe that (59a) loses out to the form in which the anti-structure is preserved, namely (59b), because it violates MAX-CONS-μ.[21] The reason the highest ranking constraint in (59) is the specific FAITH constraint MAX-CONS-μ rather than a general one, i.e. MAX-μ, is that the general constraint would incorrectly predict that candidate (56a) be selected over (56b). Note, however, that the specific constraint MAX-CONS-μ does not effect the outcome in (56) because the mora that is deleted is vocalic and not consonantal.

A comparison of the language-specific ranking in (60) with the general one in (6) reveals that Afar is yet another example of a language with anti-structure preservation effects. This being said, it needs to be emphasized here that not all cases of anti-gemination exhibit anti-structure preservation effects. For example, in the Coahuiltecan language Tonkawa, spoken in Texas, a syncope rule applies similar to the one in Afar (see McCarthy 1986: 223ff.). As in Afar, syncope in Tonkawa is blocked if the output would be a geminate, but in contrast to Afar, Tonkawa has no underlying geminates. Thus, Tonkawa syncope is an example of a language with a blocking effect (since there are no anti-structures in the language) which would be captured with the general ranking in (5).

4 Conclusion

In the preceding paragraphs I have examined a number of case studies from several languages illustrating anti-structure-preservation effects and have demonstrated that all of these examples require a language-specific instantiation of the general ranking in (6). The most important aspect of this ranking is F_A » M_A, since this is what allows the (underlying) anti-structures to surface faithfully.

What needs to be stressed is that while underlying anti-structures are preserved in the phonetic form by the ranking F_A » M_A, *derived* anti-structures are not allowed to surface in the present analysis. Thus, consider a hypothetical language like German with a process of glide formation of the form /i/ → [j] / __ V, which is blocked before /i/. A derived anti-structure would be some word, e.g. /aki-in/, which surfaces exceptionally as [akjin]. An example like [akjin] from /aki-in/ in this hypothetical language could not surface in the present treatment because the ranking F_A » M_A only allows for underlying anti-structures /ji/ to be preserved in the output as [ji]. In rule-based approaches one would presumably analyze derived anti-structure preservation effects either as idiosyncratic exceptions to the filter banning [ji], or in terms of level ordering. For example, a form like [akjin] from /aki-in/ might

[21] McCarthy (1986: 222) points out that syncope in Afar is not blocked if the unstressed vowel is flanked by adjacent identical consonants which are heteromorphemic. I follow Rose (2000), who proposes that the asymetrical behavior of true and fake geminates is to be expected if the OCP is limited to certain morphological domains. Since this issue is peripheral to the analysis made above I do not pursue the details here.

be regular in the sense that the [ji] filter is violated consistently before the suffix *–in*, which can be shown on independent grounds to belong to a later stratum than the [i]-initial suffixes which block glide formation.

One topic of research one might want to pursue in the future is to investigate such derived anti-structure-preservation effects. Thus, one would need to determine whether or not there are indeed such cases and if so to establish the general ranking for this phenomenon and to show how this general ranking is related to the one proposed in (6) for (underlying) anti-structure preservation effects.

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Towards a typology of stop assibilation*

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Abstract

In this article we propose that there are two universal properties for phonological stop assibilations, namely (i) assibilations cannot be triggered by /i/ unless they are also triggered by /j/, and (ii) voiced stops cannot undergo assibilations unless voiceless ones do. The article presents typological evidence from assibilations in 45 languages supporting both (i) and (ii). It is argued that assibilations are to be captured in the Optimality Theoretic framework by ranking markedness constraints grounded in perception which penalize sequences like [ti] ahead of a faith constraint which militates against the change from /t/ to some sibilant sound. The occurring language types predicted by (i) and (ii) will be shown to involve permutations of the rankings between several different markedness constraints and the one faith constraint. The article demonstrates that there exist several logically possible assibilation types which are ruled out because they would involve illicit rankings.

1 Introduction

This article examines stop assibilations – defined here as processes which convert a (coronal) stop to a sibilant affricate or fricative before high vocoids, e.g. /t/ is realized as [ts] or [s] before /i/. We propose two properties for assibilation rules which we claim are universal, namely (i) assibilations cannot be triggered by /i/ unless they are also triggered by /j/, and (ii) voiced stops cannot undergo assibilations unless voiceless ones do. The descriptive goal of this article is to test these two claims by examining assibilation processes in a large number of typologically diverse languages. Theoretically we propose that assibilations are to be captured in the Optimality Theoretic framework (henceforth OT; Prince & Smolensky 1993) by ranking phonetically grounded markedness constraints penalizing sequences like [ti] ahead of a faith constraint which militates against the change from /t/ to some sibilant sound. The occurring language types predicted by the two universal properties for assibilations referred to above will be shown to involve permutations of the rankings between several different markedness constraints and the one faith constraint. A major claim of the present article is that there exist several logically possible assibilation types which can all be ruled out because they would involve illicit rankings.

The present treatment is important for several reasons. First, we provide additional evidence that phonological assibilations can only be adequately explained by appealing to phonetics (see also Clements 1999 and Kim 2001). Our study supplements the aforementioned studies, since neither linguist considers the properties in (i) and (ii). Second, we argue that the markedness constraints which trigger assibilations are based in perception and that they are therefore not speaker-driven. In this respect our treatment differs significantly from traditional markedness constraints in OT, which are typically based in articulation. Third, we show how our analysis of assibilations is superior to the one proposed by Kirchner (1998), who attempts to capture this process with a fortition constraint. Finally, our study shows how the OT framework can capture occurring vs. non-occurring rule types by

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appealing to a universal constraint hierarchy among markedness constraints whose universal ranking is based on phonetics (see also Boersma 1998 and Hamann 2003, who propose similar hierarchies).

The article is structured as follows. In §2 we discuss stop assibilations from the phonetic perspective and show that these processes are characterized by several general properties (based on the findings of Clements 1999 and Kim 2001). In §3 we discuss the two universal properties for assibilations referred to above and posit a typology of six language types which we show are attested in a number of languages. By contrast, there are at least five logically possible assibilation types that will be shown not to be attested. In §4 we posit an OT analysis of the typological generalizations presented in §3 which accounts for the six occurring assibilation types while simultaneously ruling out the five nonoccurring types. §5 concludes.

1 Stop assibilations

In this section we define what we mean by stop assibilation and then present several universal properties for such processes (discussed by Clements 1999 and Kim 2001).[1]

Stop assibilations (or assibilations for short) are defined here as processes whereby stops become sibilant affricates or sibilant fricatives before high vocoids. Three examples of such rules have been presented in (1).

(1) Three examples of assibilation rules:

a. t → s / __ i	Finnish (Kiparsky 1973)	spirantization
b. t t^h → ts ts^h / __ i	Korean (Kim 2001)	affrication
c. t → tʃ / __ i	West Futuna-Aniwa (Daugherty 1983)	palatalization

We classify the three assibilation processes in (1) according to their output; thus, we call rules like the one in (1a-c) 'spirantizations', 'affrications' and 'palatalizations' respectively. Although we are primarily interested in affrications and spirantizations (because these processes are not as well studied as palatalizations) we include palatalizations in the typology we posit below for three reasons. First, many languages have processes which have as the output either [ts] or [tʃ]. Second, palatalizations seem to obey the same kinds of generalizations as affrications and spirantizations, namely the two universal properties referred to in §1. And third, the three processes arguably have the same function of avoiding surface sequences like [ti].

Although processes like the ones in (1) can also affect a velar stop (e.g. in Late Latin /k g/ surfaced as [ts dz] before /j/; Pope 1952) and in some rare languages a labial (e.g. in Lahu labial stops and nasals are affricated before /u/; Mattisoff 1982: 3), we restrict our typology in §3 and the analysis in §4 to assibilations which have a coronal stop as the input segment, in particular the input is dental or alveolar, i.e. [+coronal, +anterior] in terms of features.

Assibilations like the ones in (1) can either be lexical or postlexical rules. For example, in Korean (see 1b) assibilation is lexical because it is restricted to applying within a derived environment and does not affect tautomorphemic /ti/, /t^hi/ sequences. In Quebec French (Cedegren, Archambault & Boulianne 1991, Kim 2001) the assibilation rule is

[1] In addition to the two studies mentioned above the previous literature on stop assibilations includes Foley (1973, 1977) and Bhat (1978). It should be noted that the often cited typological study of Bhat (1978) does not discuss the issues we treat below.

postlexical because it applies across the board, both within and across words. Since the properties we discuss below hold for postlexical and lexical assibilations we do not see the need to distinguish between the two rule domains. On similar lines we discuss both synchronic rules of assibilation as well as diachronic ones because both processes display the properties we discuss below.

The term 'assibilation' is used here in a very narrow sense since we restrict our discussion below to processes like the ones in (1), which share the following three properties (based on the findings of Foley 1973, 1977, Clements 1999 and Kim 2001):

(2) Three properties of stop assibilations:

a. the trigger is some subset of the high front vocoids (i.e. /i y j/)
b. the output is a sibilant (either an affricate or a fricative)
c. the trigger is to the right of the target

Kim (2001) and Clements (1999) offer a phonetic explanation for the properties of stop assibilation in (2a-c). The creation of sibilants from stops has its phonetic origin in the brief period of turbulence (or 'friction phase') which occurs at the release of a stop into a following high vocoid. Thus, Clements (1999) and Kim (2001) show that stridency is generated when the tongue moves from the oral closure of a coronal stop into the position required for the articulation of a high vocoid (see also Ohala 1983). This phonetic explanation is captured directly in the markedness constraints we propose in §4.

The properties in (2) are strong cross-linguistic tendencies. In (3) we have listed processes which violate one or more of them:

(3) Exceptions to the properties in (2):

a.	t → s / __ i, u, e, o	Woleaian (Tawerilmang & Sohn 1984: 184)
b.	t → θ / i __	Tümpisa Shoshone (Dayley 1989: 407)
c.	t d → tʃ dʒ / i __	Pima Bajo (Fernandez 1996: 4)
	t → tʃ / i __	Apalai (Koehn & Koehn 1986: 120)
	t → tʃ / i __	Basque (Hualde 1991: 108-109)

In (3a) we have presented an example of a language in which assibilation is not triggered by a subset of the high front vocoids. The process in (3b) is the only example to our knowledge of a process in which a nonsibilant fricative is the output, but which is in line with most of the other properties in (2). Finally, in (3c) we have listed three languages in which the trigger is to the left of the stop (this also holds for 3b).

In many languages stops change to sibilant affricates or sibilant fricatives but the rules are not conditioned by a vocalic element. Although these processes are often referred to as 'assibilations' in the literature, we exclude them from our analysis because we focus only on processes like the ones in (1) which are triggered by high (front) vocoids. Three examples of the kinds of processes we will not discuss are presented in (4):

(4) Examples of changes excluded by our definition of assibilation:

a. t → ts / # __	Old High German (Penzl 1972)
b. t → ts / ▯[__	Danish (Basbøll & Wagner 1985: 67).
c. t d → ts dz / __ s z ts dz s̢ z̢ ts̢ dz̢	Polish (Rubach 1994)

The Old High German example in (4a) is a sound change that transpired in the sixth and seventh centuries.[2] The process in (4b) is apparently an allophonic one in Modern Danish. The rule in (4c) is an optional process in Modern Polish.

1 Typology of assibilations

In this section we present a typology of assibilation rules like the ones in (1) on the basis of our investigation of assibilations in 45 languages (see the appendix for a complete list of the languages discussed in this article and the respective genetic classification). In §3.1 we posit a set of ten logically possible assibilation types, only five of which we maintain are actually attested. The five nonoccurring types will be shown to be excluded due to two properties of assibilations we propose below. In §3.2 we present examples of all of the five occurring assibilation types. (A sixth occurring type will be discussed in §4.3).

1.1 Introduction

Recall from (2b) that the trigger for stop assibilation is typically some set of the high front vocoids (i.e. the vowel /i/ and glide /j/). Given the two triggers /i/ and /j/ there are four logical assibilations, which we have listed in (5):

(5) a. Assibilation is triggered by /i/ and /j/
b. Assibilation is triggered only by /j/
c. Assibilation is triggered only by /i/
d. Assibilation is triggered by neither /i/ nor /j/

The second property we discuss concerns the sounds undergoing assibilations, in particular we investigate the difference between voiceless and voiced stops in the input. Thus, given the two input segments /t/ and /d/, four possible assibilations are summarized in (6):

(6) a. /t/ and /d/ assibilate
b. Only /t/ assibilates
c. Only /d/ assibilates
d. Neither /t/ nor /d/ assibilate

Combining the eight variables in (5) and (6) yields sixteen logically possible assibilation types. Four of these sixteen combinations involve variable (6d), i.e. alveolar stops do not assibilate at all (=6d+5a, 6d+5b, 6d+5c, 6d+5d). We have classified all four of these combinations into one language type, namely type E (see 7 below). Three of the remaining twelve combinations show assibilation without a high front vocoid trigger (i.e. 5d+6a, 5d+6b, 5d+6c). Examples for these kinds of assibilations (i.e. those in which the trigger is not some high vocoid) were given under (4). Since these rule types are not topic of the present article we do not include them in our typology in (7). The remaining nine combinations correspond to the additional language types in (7) and (8) (i.e. A-D, F-J). In this typology we have two general categories (to be justified in §3.2), namely assibilation types which are occurring (types A-E) and those which are not (types F-J).

[2] In addition to the word-initial context in (4a) /t/ was assibilated to [ts] in other environments as well, e.g. after /r/ in words like *her[ts]a* (cf. the English cognate *heart*). In addition, /p/ and /k/ surfaced as the corresponding affricates.

(7) *Occurring assibilation types:*

Language Type	*assibilating segment(s)*	*trigger(s)*	
A	/t d/	/i j/	6a + 5a
B	/t d/	/j/	6a + 5b
C	/t/	/i j/	6b + 5a
D	/t/	/j/	6b + 5b
E	none	/i j/, /i/, /j/, none	6d + (5a, 5b, 5c, 5d)

(8) *Nonoccurring assibilation types:*

Language Type	*assibilating segment(s)*	*trigger(s)*	
F	/t d/	/i/	6a + 5c
G	/t/	/i/	6b + 5c
H	/d/	/i j/	6c + 5a
I	/d/	/j/	6c + 5b
J	/d/	/i/	6c + 5c

The typology in (7-8) takes all three assibilation types in (1) into consideration, i.e. affrications, spirantizations and palatalizations. Thus, we show below in §3.2 that these three assibilation types are attested for the occurring types in (7), and none of the three assibilation types is attested in the five languages in (8).

We argue here that the nonoccurring language types in (8) are true 'systematic gaps' whose absense can be accounted for with the following two universal properties of assibilations.[3]

(9) Two additional properties of stop assibilations:
  a. Assibilation cannot be triggered by /i/ unless it is also triggered by /j/.
  b. Voiced stops cannot undergo assibilations unless voiceless ones do.

In §3.2 we present examples of languages corresponding to the various language types in (7), thereby lending support to the two properties in (9). §4 we present phonetically grounded constraints which account for why the properties in (9) hold.

We noted above in §2 that our study is restricted to assibilations in which the input consists of an (oral) stop, but we hypothesize that the same generalizations holds for 'assibilations' in the broad sense of the word. For example, our impressionistic view of velar palatalizations suggests that property (9a) also holds. (9a) may also hold for processes of palatalization in which the input is some sound other than a nonstrident stop, e.g. fricatives like /s z/, as well as nasals and laterals (see also our remarks in §3.2.2 for Baztan Basque). It may even hold for processes not commonly characterized as assibilations, e.g. the change from /θ/ to [s] before /i, iː, j/ in Plains Cree (Wolfart 1973: 79). Further research will also determine whether (9a) can be generalized to all gildes and high vowels and not simply /i/ and /j/. We also hypothesize that (9b) is valid for processes like the ones in (4) above, in which the trigger is not a vocalic element. Further research is therefore required to determine the extent to which (9a) and (9b) hold for other phonological processes.

Property (9a) can be tested by scrutinizing languages with sequences like /tj/ and /ti/ in which assibilation affects /t/. Our study is confounded by the fact that in many assibilating languages there is a strict phonotactic restriction prohibiting /Cj/ sequences (or more

[3] Foley (1973, 1977) proposes what he seems to consider a universal generalization for assibilations which is equivalent to (9a), but he only discusses examples from English and French in support of it. To our knowledge no one to date has proposed (9b).

generally, any sequence of nonsyllabic segments). It is important to stress here that (9a) cannot be refuted with a language which assibilates /t/ before /i/ and which simply does not have any /tj/ sequences. Thus, this example is not Type G, but instead Type C. A similar point can be made with respect to /t/ and /d/ as inputs. Hence, if a language assibilates /t/ before /i j/ then it can only be classified as Type C if there are /di dj/ sequences which do not assibilate. If this language has no /di dj/ sequences to begin with then this language is not Type C, but instead Type A. Type G and Type C are illustrated in (10a, b) respectively. The language described above, in which /ti/ assibilates but which does not have /tj/, is classified as Type C (see 10c).

(10) a. A nonoccurring assibilation rule (Type G):
/ti/ → [tsi]
/tj/ → [tj]
(/di/ does not assibilate)
b. An occurring assibilation rule (Type C):
/ti/ → [tsi]
/tj/ → [tsj]
(/di dj/ do not assibilate)
c. An occurring assibilation rule (Type C):
/ti/ → [tsi]
(/tj/ does not occur; /di/ does not assibilate)

1.1 The occurring language types

In this section we present examples from language types A-E. In our typology we present 45 assibilation rules (as defined in §2) in a typologically and geographically diverse set of languages (see the appendix). Our survey subsumes the three kinds of assibilations in (1). The assibilations listed below include purely allophonic (postlexical) processes, as well as neutralizing and highly morphologized (i.e. lexical) assibilations. Historical processes are included as well. Although our analysis in §4 is only intended to account for the assibilation of anterior sounds before high front vowels, we have also included below assibilations triggered by other vocalic elements (e.g. high back vowels, mid vowels) because these rules seem to obey the same generalizations in (9).

It will become evident below that there is an unequal distribution among language types, in particular, types A, C and E are represented by many languages whereas only a very small number belong to types B and D. Among the A, C and E languages it appears that types A and E outnumber those of type C. We hypothesize that this unequal distribution is truly systematic and that these patterns would be confirmed by investigating assibilations in additional languages. Since we take the unequal distribution among the various types as systematic and not accidental we discuss a possible reason for it in §4.4 below.

1.1.1 Type A

Examples of Type A languages have been presented in (11). In the second column we list the corresponding rule type.

(11) *Type A languages:*	*assibilation type:*
a. Quebec French (Cedegren et al. 1991)	affrication
b. Kpándo (Vhe) dialect of Gbe (Capo 1991: 99ff.)	affrication
c. Nishnaabemwin (Valentine 2001: 86ff.)	palatalization

d. Nyakyusa (Labroussi 1999: 341)	spirantization
e. Runyoro-Rutooro (Rubongoya 1999: 27)	spirantization
f. Japanese (Itô & Mester 1995)	affrication, palatalization
g. Sorbian (Wowčerk 1954: 24-25)	palatalization
h. Koyra Chiini and Humburi Senni (Heath 1999: 34)	palatalization
i. Fongbe dialect of Gbe (Lefebre & Brousseau 2002: 21)	affrication
j. Papago (Hale 1965)	palatalization
k. Taiof (Lynch, Ross & Crowley 2002: 426f.)	affrication, palatalization
l. Mongo (Spaandonck 1964)	affrication
m. Rundi (Spaandonck 1964: 192f.)	palatalization
n. Ancient Greek (Sommerstein 1973: 15)	spirantization
o. Plains Cree (Wolfart 1973: 79)	affrication
p. Wai Wai (Hawkins 1998: 160)	palatalization
q. West Greenlandic (Fortescue 1984: 333)	affrication
r. Finnish (Sulkala & Karjalainen 1992)	affrication
s. Maori (Bauer 1993: 530f.)	affrication
t. Cheyenne (Davis 1962: 36)	affrication, palatalization
u. Samoan (Mosel & Hovdhaugen 1992: 21)	affrication
v. Blackfoot (Frantz 1991: 16, 26)	affrication
w. Axininca Campa (Spring 1992: 339)	affrication
x. Korean (Kim 2001: 89ff.)	affrication
y. Nauran (Kayser 1993: 2)	affrication
z. Sonora Yaqui (Dedrick & Casad 1999: 9)	palatalization
a'. West Futuna-Aniwa (Dougherty 1983)	palatalization

A straightforward example of a Type A language is illustrated with the data in (12) from Quebec French (see 11a; data from Kim 2001: 91):

(12) Stop assibilation in Quebec French:

Standard French	*Quebec French*	*gloss*
[ti]pe	[tsi]pe	‘type’
[di]x	[dzi]x	‘ten’
[tj]ens	[tsj]ens	‘(I) hold’
[dj]eu	[dzj]eu	‘God’

The data in (12) show that /t d/ assibilate to [ts dz] before /i/ and /j/.

A second example of a Type A language is illustrated with the (historical) process of assibilation in the Kpándo (Vhe) dialect of Gbe (see 11b). In the first column the relevant sequences in Proto-Gbe are presented and in the corresponding line of the second column the same sequences in the daughter language Kpándo (Vhe) (data from Capo 1991: 99-100, 104-105).[4]

[4] Throughout this article we use transcriptions which are in accordance with the IPA; hence, in certain examples we have translated the symbols with the equivalent IPA sounds. For example, in (13) Capo’s [y] = [j] and his [t^s d^z] are rendered in (13) as [ts dz]. In the data in (13) and in following tone languages the tones have been omitted.

(13) Stop assibilation in the Kpándo (Vhe) dialect of Gbe:

	Proto-Gbe	*Kpándo (Vhe)*	*gloss*
a.	*-ti	[atsi]	‘tree’
	*tiə	[tsi]	‘be fed up’
	*diədiə	[dzidzi]	‘be far’
b.	*tjã	[tsja]	‘to choose’
	*djɔ	[dzɔ]	‘happen’
c.	*tu	[tu]	‘to grind’
	*dũ	[du]	‘fetch water’
	*te	[te]	‘to deprive’
	*-ta	[eta]	‘head’

In (13a) it can be observed that /t d/ assibilate to [ts dz] before /i/. That the palatal glide /j/ triggers the same process is shown in (13b). (In the second example in 13b the palatal glide /j/ was deleted after triggering assibilation of the preceding /d/). The remaining data in (13c) show that none of the other vowels in the language triggers stop assibilation.

The Algonquian language Nishnaabemwin in (11c) has a lexical process of palatalization whereby /t d/surface as [tʃ dʒ] before morphemes that start with /i/, /ɪ/, and /j/ (Valentine 2001: 86ff.):

(14) Stop palatalization in Nishnaabemwin:

a.	/mɑːd-jɑː/	[mɑːdʒɑː]	‘leave/take off’
	/biːd-ɪ-bɪzɔ/	[biːdʒbɪzɔ]	‘come driving’
	/piːt-ɪ-gɪ/	[piːtʃgɪ]	‘grow to such extent’
b.	/biːd-ɑː-dɑge/	[biːdɑdge]	‘come swimming’
	/piːt-ɑː/	[piːtɑː]	‘have height to such extent’

In (14a) examples are given where palatalization occurs (the triggers /i/ and /j/ have been subsequently deleted by syncope, see Valentine 2001), and in (14b) examples with an ɑ-initial morpheme where no palatalization takes place. The Bantu language Nyakyusa in (11d) has a lexical process whereby the causative morphemes *-i-* [j] and *-isy-* [ɪsj] cause spirantization of /t d/ to [s] (Labroussi 1999: 341), e.g. the stems *-end-a* ‘walk’ and *-and-a* ‘start’ change to [–eːs-j-a] ‘cause to walk’, and [and-ɪsj-a] ‘make someone to begin’ respectively. Runyoro-Rutooro in (11e) spirantizes /t/ to [s] and /nd/ to [nz] if affixes are added that begin with /i/, /e/ or /j/ (Rubongoya 1999: 27). In Japanese (11f; Ito & Mester 1995: 825ff.) /ti/ surfaces as [tɕi], e.g. /kat-i/ ‘win’ (infinitive) is realized as [katɕi], and /di/ as [dʒi], e.g. in the loanword *dilemma* as [dʒiɽemma]. The high back vowel [u] (= [ɯ] in a narrow transcription) causes affrication of the preceding alveolar stop, thus /kat-u/ ‘win’ (pres.) surfaces as [katsu]. Japanese has no native sequences of *tj* or *dj*, but loanwords show that /j/ after alveolar stops also triggers palatalization (Ito & Mester 1995: 837), e.g. *tube* [tɕuːbu], and *juice* [dʒuːsu]. Sorbian (11g; Wowčerk 1954: 24-25) palatalizes /t d/ before /i j/, e.g. *hró[d]* ‘castle’ vs. *na hró[dʒ]e* ‘on the castle’ (from /d+j/), *hró[dʒ]ik* ‘small castle’ (from /d+i/).

Examples (11h-n) are classified as such due to defective distributions of either the glide or the voiced alveolar stop. For example, Koyra Chiini and Humburi Senni (see 11h) underwent a diachronic process whereby both /t d/ changed to [tʃ] before /i/, e.g. [tʃi] ‘be’ in Koyra Chiini and Humburi Senni with [ti] in the neighboring language Koyraboro (Heath 1999: 34). In the Fongbe dialect of Gbe (see 11i) /t d/ assibilate before /i/ (Lefebre & Brousseau 2002: 21), e.g. /ti/ → [tsi] ‘squeeze’, /ɗĩ/ → [dzĩ] ‘be very good’ (tones are omitted in these examples). Papago (also called O'Odham; see 11j) similarly palatalizes /t d/ to [tʃ dʒ] before /i u/ (Hale 1965: 299ff). In Taiof (see 11k) /t/ assibilates to [ts] before /i/ and /d/ to [dz] before /i u/ (Lynch, Ross & Crowley 2002: 426f.). In Mongo and Rundi (see 11l, m) the nominalizing suffix *–i* causes the palatalization of /t/, /^{n}d/ (and n) (Spaandonck 1964: 192), e.g. Mongo /-lot-/ 'flee' vs. [-lotsi] 'fugitive', /-kɛnd-/ 'go' vs. [-kɛndzi] 'traveller'. In Ancient Greek (see 11n) /t d/ spirantize to [s] in the context V __ iV (Sommerstein 1973: 15), e.g. [plûːtos] 'wealth' vs. [plúːsios] 'wealthy'. (No examples are provided with a /j/ in the assibilation context).

In Plains Cree in (11o) /t/ assibilates before /i, iː/ and before the palatal glide (Wolfart 1973: 79). The output of this assibilation is a sound which ranges from 'a blade-alveolar to a dorso-laminal affricate'. Since Plains Cree has no /d/ which could potentially assibilate we classify it as a Type A language. The situation is the same in the Amazonian language Wai Wai in (see 11p), which has a lexical process of palatalizing /t/ → [tʃ], e.g. /t+irko/ [tʃirko] 'fix/make it' (Hawkins 1998: 160), but there is no /d/ which could potentially assibilate. Wai Wai has a glide /j/, but this sound cannot occur after /t/ (Hawkins 1998: 150).

In the final eleven languages (see 11q-a') there is neither a /d/ which could potentially assibilate, nor a /j/ which could potentially serve as the trigger. For example, in West Greenlandic (see 11q) singleton and geminate /t/ are assibilated to [ts] in all contexts but this language has no /d/, and /j/ never surfaces after alveolar stops (see Fortescue 1984: 335). In Finnish (11r) there is a lexical rule spirantizing /t/ in stems that end in *–te* before the nominative morpheme *–i* and the plural morpheme *–i*, e.g. *sute vs. susi* 'wolf (ess. – nom.)' (Sulkala & Karjalainen 1992). Finnish has no j-initial morphemes to trigger a similar change, and also no d that could undergo spirantization. Both Maori (see 11s; Bauer 1993: 530f.) and Cheyenne (11t) have assibilations triggered by /i/, e.g. /t/ assibilates to [ts] in the former language (with an optional realization as [tç]), e.g. *iti* 'small' is pronounced as [itsi] or [itçi]. In Samoan (11u), /t/ is affricated to [ts] before /i/ (Mosel & Hovdhaugen 1992: 20). Neither Maori, Cheyenne, nor Samoan have /d/ or a palatal glide. Based on alternations between [t] and [ts] Frantz (1991: 25) posits the rule 't → ts / __ i' for Blackfoot (see 11v). Frantz (1991: 16) writes that "the sequence *ti* never occurs in Blackfoot; whenever we would expect *ti*, we find instead *tsi*".[5] In Axininca Campa (see 11w) the morphologically-conditioned process of assibilation (referred to by Spring 1992: 339 as 'affrication') is only triggered by certain /i/-initial suffixes, e.g. the non-future tense marker /i/, e.g. /no-kant-i/ → [nokantsi] 'I said'. However, Spring does not report that assibilation is triggered by any /j/-initial morphemes. In Korean (see 11x), like Axininca Campa, assibilation is a derived environment rule which is triggered by suffixes beginning with /i/ (see Kim 2001), e.g. before the nominative suffix /i/ in /mat-i/ → [madzi] 'first child' and before the adverbial suffix /i/ in /kat^h-i/ → [kats^h-i] 'together'.[6] Kim lists no /j/-initial suffixes which could potentially trigger the rule. In Nauruan (see 11y; Kayser 1993: 2) there is an apparently allophonic rule which converts /t/ to [ts] (or [dz]); according to Kayser (1993) this language does not have /d/, nor does /j/ occur before /t/. In the Uto-Aztecan language Sonora Yaqui (see 11z) /t/ is palatalized to [tʃ] if followed by an /i/-initial morpheme (Dedrick & Casad 1999: 9). This language has neither /d/ nor a palatal glide. A purely allophonic rule converting /t/ to [tʃ] (or [dʒ]) before /i/ holds in West Futuna-Aniwa (see 11a'; Dougherty 1983).

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5 We would like to thank Fernando Zuñiga for bringing the Blackfoot data to our attention.

6 In the first example cited above the effects of an independent allophonic process of intervocalic voicing can be observed.

1.1.2 Type B

Type A languages can be contrasted with Type B languages, in which only the palatal glide but not /i/ triggers the rule. Four examples of Type B languages have been provided in (15):

(15) *Type B languages:*	*assibilation type:*
a. Romanian (Chitoran 2001)	affrication, spirantization
b. West Slavic (Carlton 1990)	affrication, spirantization
c. Sanskrit (Misra 1967: 142)	palatalization
d. Latvian (Forssman 2001: 97)	palatalization

Stop assibilation in Romanian (see 15a) is illustrated with the examples in (16) (from Chitoran 2001: 187):

(16) Stop assibilation in Romanian:

[munte]	'mountain'	[munts^j]	'mountains'
[soldat]	'soldier'	[soldats^j]	'soldiers'
[brad]	'fir tree'	[braz^j]	'fir trees'

The effects of the rule can be observed in the second column, in which it is shown that /t/ assibilates to the affricate [ts] when it bears the plural marker of secondary palatalization and that /d/ spirantizes to [z] in the same context.[7] By contrast, Chitoran (2001) lists no examples in which stop assibilation is triggered by [i].

The West Slavic example in (15b) requires some comment. According to Carlton (1990: 114) Proto-Slavic *t and *d assibilated in the various daughter languages before *j, e.g. in West Slavic *t surfaced as [ts] while *d surfaced in Polish and Slovak as [d]. We assume that affrication and spirantization were triggered by /j/, which was subsequently deleted. (Although no examples are provided for *t and *d before *i the discussion in Carleton implies that assibilation does not occur in this context). In Modern Slovak and Polish it is usually assumed that there is a morphologically-conditioned rule (called Iotation), which converts /t d/ to [ts dz] before /j/ only (Rubach 1993: 117ff.).

According to Misra (1967: 142) in Sanskrit (i.e. Old Indo-Aryan) /tj dj/ developed into geminate post-alveolar affricates, e.g. Sanskrit /satja/ 'truth' and /vidjut/ 'lightning' were later realized as /sattʃa/ and /biddʒi/ respectively. Significantly, this change was only triggered by the palatal glide and not by /i/. In Latvian (Forssman 2001: 97) [tʃ dʒ] derive historically from /tj dj/, e.g. [latʃa] 'bear (gen. sg.) (from *latsjaː, which presumably derives from /tj/).

It needs to be stressed here that we have limited our typology to those processes which have an *oral* stop as an input. If assibilations were also to subsume rules which have nasal consonants (and or laterals) as the input then the Baztan dialect of Basque would be classified as Type B/D, since in that language /n l/ palatalize to [ɲ ʎ] after the glide /j/ but not after the vowel /i/ (see Hualde 1991: 114ff.).

1.1.3 Type C

Type C languages (in which /t/ assibilates before /i/ and /j/) are listed in (17). It can be observed below that there are no examples of palatalizations among the Type C languages. At this point we assume that this gap is purely acidental.

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[7] Chitoran (2001: 185ff.) treats the process of stop assibilation in (16) as a part of a larger process she calls 'palatalization', which shifts the place of articulation for other segment types, e.g. /s/ surfaces as [ʃ] when secondarily palatalized.

(17)	*Type C languages:*	*assibilation type:*
	a. Hittite (Kimball 1999: 287ff.)	affrication
	b. Dutch (Booij 1995: 79f.)	affrication, spirantization
	c. Italian dialects (Tuttle 1997: 26f., Cordin 1997: 261)	palatalization
	d. Shona (Brauner 1995: 13)	affrication, spirantization
	e. Woleaian (Tawerilmang & Sohn 1984: 184)	spirantization
	f. Kosraean (Lee & Wang 1984: 406)	spirantization
	g. Solomon Islands languages (Tryon & Hackman 1983: 77)	affrication, spirantization
	h. Ambae (Hyslop 2001: 16-17)	spirantization
	i. Tawala (Ezard 1997: 29f.)	spirantization
	j. ‘Ala‘ala (Lynch, Ross & Crowley 2002: 347f)	spirantization
	k. Arosi (Lynch, Ross & Crowley 2002: 562)	spirantization
	l. Turkana (Dimmendaal 1983: 8-9)	spirantization

In all of the Type C languages in our survey but three (i.e. Hittite, 17a, Dutch, 17b, and some Italian dialects, 17c) /t/ assibilates before /i/, but /j/ either does not occur at all or it does exist but it never surfaces after /t/ (as in 10c). As we noted above in §3.1 the preponderance of (10c) examples over (10b) is simply indicative of the fact that many assibilating languages like the ones discussed below ban Cj sequences.

According to Kimball (1999: 287ff.) Indo-European *t assibilated to an affricate before /i j/ in Hittite (see 17a), e.g. the suffix *-tjo- in [hantetsja] ‘last’, [haːnts] ‘in front’ (from an earlier form with a final /i/). Kimball (1999: 291-292) also discusses whether or not Indo-European *d assibilated as well and concludes that the few examples which seem to suggest this development have other explanations.

Dutch (see 17b) is a language with a lexical rule that turns /t/ into [s] or [ts] after certain (Latinate) suffixes which start with [i] or [j] (Booij 1995: 79f.). These morphemes are *–i*, *–io* [ioː] ~ [joː], *–iaan* [iɑːn] ~ [jɑːn], and *–ion* [iɔn] ~ [jɔn]. Examples are provided in (18), in which /t/ surfaces as [s] after a consonant (see 18a) and as [ts] or [s] intervocalically (see 18b).

(18) a.	akt-ie	‘action’	[ɑksi]	akt-ief ‘active’	[ɑktiːf]
	president-ieel	‘presidential’	[presidɛnsjel]	president ‘id.’	[presidɛnt]
b.	relat-ie	‘relation’	[relatsi] ~ [relasi]	relat-ief ‘relative’	[relatiːf]
	rat-io	‘ratio’	[ratsijoː] ~ [rasjoː]	rat-ificeer ‘to ratify’	[ratifiseːr]

In the Northern Venetian dialect of Italian (see 17c), /t/ palatalized before /i/ and /j/. Thus the Old Venetian form [tiol] ‘he removes’ is now realized as [tʃol], and [tjɛni] ‘hold’ as [tʃeŋ] (Tuttle 1997: 26). Furthermore, Tuttle (1997: 30) reports that the inflectional plural marker *-i*, which became a glide before vowels in rapid speech and was later lost, palatalized the preceding /t/ in Ticino. Examples are *quanti* ‘how much’ (pl.) which is realized as [kwɛntʃ] and *alti* ‘high’ (pl.) as [altʃ] or [ɛltʃ]. In the Trentino dialect a similar process must have taken place, as the example *gatti* ‘cats’ [gatʃ] from Cordin (1997: 261) suggests.

Assibilation as diachronic process occurred in the development of Shona (see 17d), where Proto-Bantu /ti/ changed to [tsi] after a vowel and to [si] word-initally (Brauner 1995: 13), see (19).

(19) Stop assibilation and spirantization in Shona:

Proto-Bantu	*gloss*	*Shona*	*gloss*
*-tima	'displant'	[-sima]	'transplant'
*piti	'hyena'	[sʊitsi]	'spotted hyena'

Shona has a voiced stop /d/ (written as 'dh') in loanwords only, e.g. *dhora* 'dollar', which is not reported to undergo assibilation (Brauner 1995: 10).

Historical assibilations transpired in a number of Austronesian languages in the Oceanic branch (17e-i). For example in Woleaian (see 17e) there was a diachronic process of assibilation which converted Proto-Oceanic *t into [s] before /i u e o/, as in (20) (Taweril-mang & Sohn 1984: 184):

(20)

Proto-Oceanic		*Woleaian*	
*tama	>	tama	'father'
*ʔatop	>	aso	'thatch'
*mate	>	mase	'to die'
*tika	>	sixa	'bad, angry'
*ʔatun	>	asu	'louse'

A similar process transpired in the history of Kosraean (see 17f; Lee & Wang 1984: 406). According to this source, Proto-Oceanic *t surfaced as [s] before front vowels (but *d was not affected). Tryon & Hackman (1983: 77) note that an assibilation affected Proto-Oceanic *t in the Solomon Islands languages (17f) Vaghua, Varisi, Ririo and Sengga (also known as Central-East Choiseul), all spoken on the island of Choiseul. In the first of these languages the assibilation was an affrication which went into effect before high vowels and in the final three it was an assibilation triggered by /i/. In all of these languages Proto-Oceanic *d surfaced as [r]. According to Hyslop (2001: 26) in all dialects of Ambae (see 17h; Oceanic, Vanuatu) except for Lolokaro a fricative [s] developed from Proto-Oceanic /t/ before /i/, as in (21):

(21) Stop spirantization in Ambae:

Proto-Oceanic		*Ambae*	*gloss*
*tibo-	>	sibo-	'self'
*pati	>	βesi	'four'

Proto-Oceanic had a /d/ and a /j/, but allowed only CV syllables (Lynch, Ross & Crowley 2002: 65). Proto-Oceanic *d became a prenasalized voiced alveolar stop [^{n}d] in the dialects of Ambae in all contexts, e.g. *didiu* 'ant' is realized as [^{n}dɪ^{n}diɯ] (Hyslop 2001: 29). Tawala (see 17i; Ezard 1997) underwent a diachronic process whereby /t/ was fricativized to [s] before the high front vowel /i/. According to Ezard (1997: 30), "the dialect variation of some forms reflect this rule", e.g. [emota]~ [emosi] 'one', [hota] ~ [hosi] 'only'. By contrast, /d/ remained unchanged, cf. *badila* [badila] 'the name of a native almond'. Tawala has also a palatal glide, but does not allow other than (C)V syllables, thus a potential sequence tjV to trigger spirantization does not occur.

Synchronic processes of assibilation are also common in Oceanic languages. For example, in 'Ala'ala (see 17j; Lynch, Ross & Crowley 2002: 347f) spirantization creates the allophone [s] from /t/ before /i/, e.g. /ʔiti/ 'upward' surfaces as [ʔisi] but /aʔate/ 'women' as [aʔate]. /d/ remains unchanged in this language, e.g. /nodi/ surfaces as [nodi] 'coughs' (Lynch et al. 2002: 348). 'Ala'ala is not reported to have a palatal glide. In Arosi (see 17k) the contrast between /t/ and /s/ is neutralized to [s] before /i/ (Lynch, Ross & Crowley 2002: 562).

In Turkana (see 17l) Dimmendaal (1983: 8-9) reports that /t/ (but not /d/) spirantizes to [s] before suffixes beginning with a front vowel, e.g. /a-kɪ-mat/ ‘to drink’ vs. /a-mat-ɪ/ → [amasɪ] ‘I am drinking’. (Although this language has a /j/, no examples are provided with a suffix beginning with /j/ which occurs after a stem ending in /t/).

1.1.4 Type D

In Type D languages /t/ assibilates before [j]. Examples are provided in (22).[8] The lack of Type D languages which exhibit spirantization and palatalization is probably accidental, due to the small number of languages belonging to this category.

(22) *Type D languages:*	*assibilation type:*
a. Latin (Pope 1952)	affrication
b. German (Hall 2003)	affrication

Stop assibilation in Latin is illustrated in (23). According to Pope (1952: 129ff.) and Jacobs (1989: 117ff) /t/ affricated to [ts] before /j/ in the course of Late Latin. Pope (1952: 129) writes that the change is attested as early as the fourth century. This development is illustrated with the examples in (23) from Pope (1952: 130):

(23) Stop assibilation in Late Latin:

*fortja	>	*fortsja	‘force’
*faktjone	>	fatsun	‘manner’

In contrast to the assibilation in (23), Pope (1952: 129) notes that the same process did not affect /dj/.[9]

Stop assibilation in German is illustrated with the data in (24) (from Hall 2003). That this is a regular process of the language and not simply an inheritance from Latin is discussed in that source.

(24) Stop assibilation in German:

Negation	[negaˈtsjoːn]	‘negation’	negativ	[ˈneːgatiːf]	‘negative’
Konsortium	[kɔnˈzɔɐtsjʊm]	‘syndicate’	Konsorten	[kɔnˈzɔɐtən]	‘gang’

In these examples we can observe an assibilation of /t/ to [ts] before /j/. The example *negativ* in the second column is important because it shows that the rule is not triggered by the vowel /i/. Examples like *Studium* [ʃtuːdjʊm] ‘studies (sg.)’ show that assibilation only affects /t/ and not /d/.

1.1.5 Type E

Type E languages are those in which no segments assibilate. Our main descriptive goal in this article has been to find examples of languages with assibilations, so we do not claim to have an extensive list of Type E languages. However, we do maintain that languages belonging to Type E are extremely common. One example of a Type E language is Chamorro (see 25a). According to Topping's (1973) description of the phonology there are no processes in this

8 An additional example of a Type D language may be certain dialects of Albanian. Buchholz & Fiedler (1987: 38) note that /tj/ surfaces as [ts] in Central Albanian, but they write that this only occurs in certain words.

9 Word-initial /dj/ surfaced first as a voiced palatal stop [ɟ] and then later on as [dʒ]; intervocalically /dj/ went to [ɟ] and then to [j]; see also Sommer (1948), who agrees that there was a stage in the history of Latin with [ɟ]).

language resembling assibilations as defined in §2. Although Lahu (see 25b) is one of the few languages in which labials assibilate (recall §2), this language has no process of assibilation in which the input is a coronal stop (Matisoff 1982). We speculate here that certain language families (and possible linguistic areas) tend not to assibilate /t d/. One example is illustrated by the indiginous languages of Australia (see Dixon 1980 for a survey). Two examples of Australian languages are provided in (25c, d). In neither of these descriptions is reference made to assibilation processes.

(25) *Type E languages:*

a. Chamorro (Topping 1973)
b. Lahu (Matisoff 1982)
c. Nhanda (Blevins 2001)
d. Gaagudju (Harvey 2002)

A possible reason for the lack of spirantizations and affrications in Australian languages might be that the typical Australian language does not have fricatives or affricates (i.e. [ts]). Note that the ban on sounds like [s] and [ts] in typical Australian languages is also enforced at the level of grammar where allophonic rules go into effect (i.e. postlexically).

1 A formal analysis

In this section we present a formal OT analysis of the typology in §3.2. Specifically, we show that assibilation is captured by ranking one or more markedness constraint ahead of a faith constraint which militates against changing the feature [strident]. It will be argued below that the markedness constraints required to capture assibilations are grounded in phonetics and that a (phonetically motivated) universal ranking can be posited which rules out all of the nonoccurring language types in (8). The occurring language types in (7) (discussed in §3.2) will be shown to involve the ranking of the one faith constraint with respect to the universal ranking for markedness constraints. In the following analysis we only restrict ourselves to the assibilation of alveolar stops before high fronts vocoids. Other kinds of assibilation processes (e.g. those in which the process is triggered by other vowels, those in which velars form the input) require markedness (and/or faith) constraints not discussed below.

1.1 Phonetically grounded markedness constraints

As described in §2, the release of an alveolar stop into a high front vocoid causes a period of turbulence (or ‘friction phase’; see Clements 1999, Kim 2001) which is significantly greater than the friction phase of the same stop which is released into a non-high and/or non-front vocoid. The period of turbulent air stream that emerges at the release of an alveolar stop into a high front vocoid has acoustically the same characteristics as the friction noise caused by an alveolar strident fricative. For a listener it is therefore difficult *not* to perceive the friction phase of the stop-vocoid sequence as a separate fricative. This is the function of the (perceptual) markedness constraint *tj in (26a).

(26) Two markedness constraints:

a. *tj: The sequence /tj/ cannot be perceived as such/without a fricative.
b. *ti: The sequence /ti/ cannot be perceived as such.

Markedness constraints that refer to perceptual or auditory information is not new in phonology; see, for instance, Flemming’s (1995) MINDIST constraints and Steriade’s (2001) correpsondence constraints that are based on a perceptual map (the so-called ‘P-map’).

Kirchner (1998: 117ff.) also posits perceptually-based markedness constraints and argues that they account for assibilations. Kirchner's approach to assibilation will be compared to the present proposal at the end of this section.

The same turbulence that is present in a sequence /tj/ can also be observed in a /ti/ sequence, since the glide /j/ and the high front vowel /i/ do not differ articulatorily. Again, the listener is likely to confuse this friction noise with the presence of a fricative segment. We capture this fact with the perceptual markedness constraint *ti in (26b).

However, the total duration of the vowel /i/ is by far longer than that of the glide /j/, see Catford (2001: 68), who refers to /j/ as an 'ultra-short' /i/. The same duration of friction seems therefore shorter in a /ti/ sequence than in a /tj/ sequence. As a consequence, the friction phase in a /ti/ sequence is less likely to be perceived as a full segment than the same friction phase in a /tj/ sequence. This can be expressed as universal ranking between the two markedness constraints in (27). Similar universal constraint rankings grounded in phonetics are proposed by Boersma (1998) and Hamann (2003).[10]

(27) A universal ranking:
*tj » *ti

An argument that the length of the frication phase is perceived in relation to the overall duration of the sequence is illustrated by assibilation in Finnic. Here the /t/ was fricativized to [s] before a high front vowel, but the geminate /tt/ remained unchanged (Posti 1954: 51). This can be explained by the fact that the friction phase is perceived as longer if it follows a singleton than if it follows a geminate plosive.

In §3 it was shown that languages differ in the voicing of the stops that undergo assibilation. For the voiced stops, the two constraints *dj and *di can be stated (see 28). Like the constraints in (26) the ones in (28) express the perceptual markedness of the relevant sequences:

(28) Two markedness constraints:
a. *dj: The sequence /dj/ cannot be perceived as such.
b. *di: The sequence /di/ cannot be perceived as such.

Since the duration of the vowel /i/ and the glide /j/ influences the perception of the friction phase for both voiced and voiceless stops in the same way, the universal constraint ranking in (29) is stated.

(29) A universal ranking:
*dj » *di

In contrast to sequences of voiceless stop plus glide /j/ or vowel /i/, sequences with voiced stops generally show less friction. This is due to two factors. First, the vibrating vocal cords of the voiced stop allow less air to build up behind the constriction in the vocal tract than when the vocal cords are open for the voiceless stops. As a consequence, there is less air pressure at the release of the voiced stop and thus less frication noise generated. Secondly, the

10 Contrary to the present analysis, both Boersma (1998) and Hamann (2003) pose underlying perceptual representations and a distinction between production and perception grammar. The OT production grammar contains perceptual faithfulness constraints and articulatory markedness constraints. An example for the latter are *DISTANCE constraints (Boersma 1998: 150, Hamann 2003: 172), which refer to the articulatory distance between different positions of an articulator, and which can be universally ranked as *DISTANCE (x, z) » *DISTANCE (x, y) if (z - x) > (y - x).

voicing of the vocal folds produces a sound which masks the frication noise, as illustrated by Catford (2001: 63) in his excersise on voiced and voiceless [i]: "As soon as you devoice [i] the hissing noise of turbulent airflow can be heard."

Taking these aerodynamic and acoustic observations into account, the constraint *tj has to be ranked above its counterpart for the voiced stop, *dj, and *ti similarly needs to outrank *di. It is not clear whether the friction noise is stronger in /ti/ sequences than in /dj/ sequences. We therefore suggest that the two constraints *ti and *dj are not universally ranked with respect to each other. In sum, the two constraint hierarchies from (27) and (29) produce the following universal ranking:

(30) A universal ranking:
*tj » {*ti, *dj} » *di

In addition to the four markedness constraints in (30), one could posit additional constraints militating against the perception of affricates, namely *tsj, *tsi, *dsj, and *dsi. The consonantal sequences referred to in these constraints include an affricate, which by definition has a fricative release. It is therefore not difficult to perceive these sequences properly, since the duration of the friction noise is long enough to be perceived as the fricative release of an affricate. Kim's data (2001: 96ff.) on the length of friction noise in Korean support this point: the friction phase in the (bimorphemic) word [matsi] 'first child' (= [madzi] in a narrow transcription) is on average 69.3 ms long, more than twice as long as the friction phase in the (monomorphemic) word [mati] 'knot'. We can conclude from this that the constraints militating against sequences of an affricate and a high vocoid are universally lower-ranked than the constraints against sequences of a stop and a high vocoid. As the constraints against affricates are not relevant for the following analyses, we will ignore them.

In sum, the markedness constraints posited above are based on the listener's inclination to parse the perceived friction noise as a separate segment. This idea differs significantly from traditional markedness constraints in OT which are speaker-driven. In Kirchner's (1998) effort-based account of lenition processes, for instance, a LAZY constraint is invoked, which militates against too much effort on the part of the speaker. As Kirchner himself shows (1998: 116ff.), the LAZY constraint alone is not sufficient to account for assibilation processes, since every assibilated output involves more articulatory effort than a non-assibilated one. To solve this problem, a so-called fortition constraint is introduced, "which serve[s] to enhance the salience and robustness of perceptual distinctions" (Kirchner 1998: 26). According to Kirchner (p. 117), a sequence such as /ti/ is automatically produced with some friction, thus possible output candidates for /ti/ are only [t^si] (with a weakly fricated release) and [tsi]. The newly introduced and highly-ranked fortition constraint *[+fricated release, –strident], requiring fricated releases to be strident, then selects the candidate [tsi] as the winner, because it has a strident release.

In Kirchner's approach the speaker thus actively decides for the strident output [tsi] to "enhance the salience and robustness of perceptual distinctions", as the definition of fortition constraints implies. However, it is not clear from Kirchner's treatment which perceptual distinction is meant to be enhanced by this output. In [tsi] the friction is without question more salient than in [t^si], but why should the output be maximally salient with respect to friction if the input has no friction at all? A major drawback of this account is that the most faithful candidate [ti] is excluded from Kirchner's OT grammar, though it should be the winning candidate according to the constraints and rankings he proposes. Furthermore, Kirchner's constraint *[+fricated release, –strident] forces the speaker to make a categorical change from a stop to an affricate articulation. This is not desirable and also not necessary, as the present approach to assibilation shows: not the exact nature of the speaker's articulation is of importance, but the perception of the listener.

1.2 An OT analysis

The typology we present below relies on the interaction between the universal ranking of the four markedness constraints in (30) with the following faith constraint:

(31) A faith constraint:
IDENT-[STRID]

The faith constraint in (31) belongs to the IDENT family; it penalizes the change from nonstrident (e.g. /t/) to strident (i.e. [ts], [s], or [tʃ]). We assume, following several authors, e.g. Jakobson *et al.* (1952), LaCharité (1993), Rubach (1994), Clements (1999) and Kehrein (2002), that stops differ from the corresponding affricates in terms of the feature [strident]. According to this view a stop like /t/ is [–strident] and an affricate like /ts/ is [+strident]. The analysis of any assibilation process requires that some markedness constraint(s) be ranked ahead of the faith constraint in (31). This point is illustrated in the tableau in (32), in which the change from /atia/ to [atsia] is shown:

(32) /atia/ → [atsia]:

	/atia/	*ti	IDENT-STRI
a.	[atia]	*!	
b.	☞ [atsia]		*

In the analysis that follows we do not distinguish between the three outputs of the assibilation processes in (1), i.e. spirantization with [s], affrication with [ts] and palatalization with [tʃ]. Instead we only discuss the manner change of stop to some strident sound (indicated as [ts] in the following tableaux) without specifying the exact phonetic realization. The different outputs (i.e. [ts] vs. [s] vs. [tʃ]) require additional constraints which are not important for capturing the typology in §3.2.

Given the universal markedness constraint hierarchy in (30) the process of assibilation is captured by ranking at least one of these constraints ahead of the IDENT constraint in (31). This ranking is illustrated in (33-36) for a Type A language (e.g. Quebec French). In these tableaux the only crucial ranking is that all four of the markedness constraints outrank the one faith constraint. Evidence for the ranking among the markedness constraints (e.g. *tj » *ti) was discussed in (30) above. It is shown below how these rankings rule out the non-occurring language types.

(33) /atja/ in Type A languages:

	/atja/	*tj	*ti	*dj	*di	IDENT-STRI
a.	[atja]	*!				
b.	☞ [atsja]					*

(34) /atia/ in Type A languages:

	/atia/	*tj	*ti	*dj	*di	IDENT-STRI
a.	[atia]		*!			
b.	☞ [atsia]					*

(35) /adja/ in Type A languages:

	/adja/	*tj	*ti	*dj	*di	IDENT-STRI
a.	[adja]			*!		
b.	☞ [adzja]					*

(36) /adia/ in Type A languages:

	/adia/	*tj	*ti	*dj	*di	IDENT-STRI
a.	[adia]				*!	
b.	☞ [adzia]					*

In these tableaux it can be observed that all four markedness constraints outrank the one faith constraint.

The occurring language types posited above in (7) are summarized in (37) with a corresponding example. In (38) we have repeated from (8) the nonoccurring language types.

(37) *Occurring assibilation types*:

	assibilating segment(s)	*trigger(s)*	*example*
A	/t d/	/i j/	Quebec French
B	/t d/	/j/	Romanian
C	/t/	/i j/	Hittite
D	/t/	/j/	Latin
E	none	none	Nhanda

(38) *Nonoccurring assibilation types*:

	assibilating segment(s)	*trigger(s)*
F	/t d/	/i/
G	/t/	/i/
H	/d/	/i j/
I	/d/	/j/
J	/d/	/i/

The universal hierarchy in (30) together with the faith constraint IDENT-[STRID] yield six rankings, five of which correspond to the occurring language types in (37). Here and below a non-ranking between the constraints in indicated with the curly brackets.[11]

(39) *Language Type* *Ranking*

	Language Type	*Ranking*
a.	Type A	*tj » {* ti, *dj} » *di » IDENT-STRI
b.	Type B	*tj » * dj » IDENT-STRI » *ti » *di
c.	Type C	*tj » * ti » IDENT-STRI » *dj » *di
d.	Type D	*tj » IDENT-STRI » {* ti, *dj} » *di
e.	Type E	IDENT-STRI » *tj » {* ti, *dj} » *di

The sixth logically possible language type is the ranking *tj » {* ti, *dj} » IDENT-STRI » *di. This language type is discussed in §4.3 below, where we show that it is in fact attested.

[11] Technically speaking a 'non-ranking' between two constraints implies two separate rankings, e.g. for Type A in (39a) two rankings:
(i) *tj » * ti » *dj » *di » IDENT-STRI
*tj » *dj » * ti » *di » IDENT-STRI
Importantly, both rankings in (i) yield the same effect.

The five language types in (37) do not occur because they would require rankings that are not in harmony with the universal rankings in (30). This point is made clear in (40):

(40) *Nonoccurring language types:*

Language Type	*Illicit Ranking*
a. Type F	{*ti, *di} » IDENT-STRI » {*tj, *dj}
b. Type G	*ti » IDENT-STRI » {*tj, *dj, *di}
c. Type H	{*dj,*di} » IDENT-STRI » {*ti, *tj}
d. Type I	*dj » IDENT-STRI » {*ti, *tj, *di}
e. Type J	*di » IDENT-STRI » {*ti, *tj, *dj}

An examination of the rankings in (40) reveals that they all violate at least one of the universal rankings in (30). Thus, Type F requires (by transitivity) that {*ti, *di} outrank {*tj, *dj} and Type G that *ti outrank *tj. Types H-J are nonoccurring because they would require *dj and/or *di to outrank *tj and/or *ti.

1.3 Additional language types

As noted in §4.2 above the constraints posited predict a sixth language type, which we refer to below as Type E':

	Language Type	*Ranking*	*Effect*
(41)	Type E'	*tj » {*ti, *dj} » IDENT-STRI » *di	t, d assibilate before j; t assibilates before i

In the final column of (41) it can be seen that the ranking for Type E' describes a 'mixed' system in the sense that it captures two separate processes, namely one which assibilates /t d/ before /j/ and the other which assibilates /t/ before /i/. In this respect Type E' is very different from Types A-D, which all describe a single process each. Note that Type E' is essentially a Type B language which also has a process assibilating /t/ before /i/. We are aware of only one Type E' language, namely English (see below); however, we speculate that additional examples might be found among the Type B languages.

The English examples in (42a) illustrate that /t d/ surface as [tʃ dʒ] before /j/-initial suffixes and the ones in (42b) that the same kind of process takes place across words (especially before the words *you* and *your*) in casual speech.[12] Importantly, neither of the two processes in (42a-b) goes into effect before a morpheme beginning with a high front vowel, e.g. *wha[t] if*, **wha[tʃ] if*.

(42) Assibilation in English:

a. perpe[tʃ]ual	(cf. perpe[t]uity)	b. wha[tʃ] you	
resi[dʒ]ual	(cf. resi[d]ue)	ha[dʒ] you	
c. democra[t]	democra[s]y		
presiden[t]	presiden[s]y		
vacan[t]	vacan[s]y		

12 We follow tradition in English phonology in assuming that the suffixes in examples like the ones in (42a) are /j/-initial, even though this segment does not surface in many dialects. It should also be noted that the process in (42a) only affects foot-internal /t d/, since these segments are not palatalized before a /j/-initial suffix which begins a foot, e.g. the underlined *t* in *perpetuity* (see Borowsky 1986).

Besides the palatalization process in (42a-b), English has a separate process which assibilates /t/ to [s] before /i/. Several alternating pairs have been listed in (42c) which motivate this process. Importantly, the process in (42c) does not affect [d], e.g. *jaggedy*, *raggedy*.

In addition to the language type in (41), there are five further examples of mixed languages, but in contrast to Type E', these five additional mixed types are all nonoccurring. The additional nonoccuring language types are listed below in (43).

(43) *Five additional nonoccurring language types*:

	assibilating segment(s)	*trigger(s)*	*Illicit ranking required*
a.	/t/	/i j/	{*tj, *ti, *di} » IDENT-STRI » * dj
	/d/	/i/	
b.	/t/	/i/	{*ti, *di, *dj} » IDENT-STRI » * tj
	/d/	/i j/	
c.	/t/	/i/	{*ti, *dj} » IDENT-STRI » {* tj, *di}
	/d/	/j/	
d.	/t/	/j/	{*tj, *di, *dj} » IDENT-STRI » * ti
	/d/	/i j/	
e.	/t/	/j/	{*tj, *di} » IDENT-STRI » {* ti, *dj}
	/d/	/i/	

As was the case in (40) each of the additional language types in (43) is nonoccurring because it would violate the universal constraint rankings in (30). Thus, the ranking {*tj, *ti, *di} » * dj in (43a) violates the universal ranking *dj » * di and in (43b, c) *ti » * tj is the opposite of the proposed ranking *tj » * ti. The ranking in (43d) requires *di to be ahead of *ti, but it was argued above that *ti » * di is universal. Finally, (43e) requires *di to outrank *dj.

1.4 Frequency

As noted above in §4.1 the distribution among the six occurring language types is not equal, since many languages fall into the A, C and E category, and only a few in B, D and E' each. What is more, Type C appears to be more common than Type A and Type E. We hypothesize that these proportions are not due to chance and therefore propose an explanation below.

We argue here that the unequal distribution among language types – in particular the cross-linguistic preference of {A, C, E} over {B, D, E'} – can be accounted for by considering whether or not the natural class of vowels and glides (i.e. [i j]) is captured by the markedness constraints. When the constraints *ti and *tj (as well as *di and *dj) are ranked together above or below the one faith constraint then we see this as evidence that [i j] function together as a unit. By contrast, if *ti and *tj (as well as *di and *dj) are ranked on opposite sides of faith then this means that [i j] do not function together as a natural class. This point can be illustrated with each of the six occurring language types in (39) and (41) to determine whether or not the natural class [i j] is respected. This is shown in (44), where we list each of the six occurring language types in the first column. In the second column '+' or '–' indicates whether or not the respective language respects or does not respect the natural class [i j] (which we symbolize here as 'i/j').

(44)

Language Type	i/j
Type A	+
Type B	–
Type C	+
Type D	–
Type E	+
Type E'	–

The table in (44) indicates that Types A, C and E are the three language types in which the natural class [i j] is respected and that Types B, D and E'are the three where [i j] are not treated as a class. The lower frequency of Type B, D, and E' languages can therefore be interpreted as a consequence of the tendency in the languages of the world to treat [i j] as a unit. That this natural class is important is substantiated by the fact that [i] and [j] are virtually the same sound from the point of view of articulatory phonetics (recall the discussion in §4.1 above). In addition, many linguists have shown that [i] and [j] are positional variants in various languages, suggesting that these two sounds are – at least in the unmarked case – one at the underlying level.

A second generalization concerning frequency is that within the A/C/E category languages of Type A and Type E seem to be more common than those belonging to Type C. This generalization can be expressed by considering the natural class of /t d/ (represented as 't/d' below), which would be satisfied if the constraints *ti and *di (as well as *tj and*dj) are ranked together with respect to the faith constraint. An examination of the rankings for Type A and Type E reveals that both of these languages satisfy the t/d natural class but this is not the case with Type C.

To summarize, the six occurring language types can be arranged in a harmonic scale, which corresponds to frequency. (See Prince & Smolensky 1993, who argue that markedness relation for segment types can be arranged in a scalar fashion, e.g. COR » LAB, which says that coronal is less marked than labial. Note that markedness in this sense is also often correlated with cross-linguistic frequency).

(45) $$\begin{bmatrix}\text{Type A}\\ \text{Type E}\end{bmatrix} \gg \left\{\text{Type C}\right\} \gg \begin{bmatrix}\text{Type B}\\ \text{Type D}\\ \text{Type E'}\end{bmatrix}$$

What this scale says is that Type A and Type E are the most harmonic assibilation types, which we interpret to mean that they are the most common ones in the languages of the world. We hypothesize that given a large enough sample of assibilations Type A and Type E will predominate over the other types. Based on our typology Type C is slightly less common than Type A and Type E but much more common than Type B, Type D and Type E'. Again, only future research can (dis)confirm the cross-linguistic predictions made by the hierarchy in (45).

2 Conclusion

In this article we proposed two new universal properties for assibilation rules and presented typological evidence from assibilations in 45 languages supporting them. We argued that assibilations are to be captured in the OT framework by ranking markedness constraints grounded in perception which penalize sequences like [ti] ahead of a faith constraint which militates against the change from /t/ to some sibilant sound. The six occurring language types were shown to involve permutations of the rankings between several different markedness constraints and the one faith constraint. The article demonstrated that there exist several logically possible assibilation types which are ruled out because they would involve illicit rankings.

Appendix

Language	Family	Geographical area	Source
'Ala'ala	Austronesian (Oceanic)	Papua New Guinea	Lynch, Ross & Crowley (2002)
Albanian	Indo-European (Albanian)	Albania	Buchholz & Fiedler (1987)
Ambae	Austronesian (Oceanic)	Vanuatu (Ambae islands)	Hyslop (2001)
Apalai	Carib	Brazil (Paru Leste River)	Koehn & Koehn (1986)
Arosi	Austronesian (Oceanic)	Solomon Islands	Lynch, Ross & Crowley (2002)
Axininca Campa	Arawakan	Peru (Pachitea River)	Spring (1992)
Blackfoot	Algic (Plains)	Canada (Alberta)	Frantz (1991)
Chamorro	Austronesian	Guam	Topping (1973)
Cheyenne	Algic (Plains)	USA (Montana)	Davis (1962)
Danish	Indo-European (Germ.)	Denmark	Basbøll & Wagner (1985)
Dutch	Indo-European (Germ.)	The Netherlands	Booij (1995)
English	Indo-European (Germ.)	United Kingdom etc.	Luick (1921)
Finnish	Uralic (Finno-Ugric)	Finland	Kiparsky (1973)
Gaagudju	Australian	Australia	Harvey (2002)
Gbe (Ewe)	Niger-Congo (Bantu)		
-Kpándo (Vhe) dialect		Ghana	Capo (1991)
-Fongbe dialect		Benin	Lefebre & Brousseau (2002)
German	Indo-European (Germ.)	Germany	Hall (2003), Penzl (1972)
Greek (Ancient)	Indo-European (Hellenic)	extinct	Sommerstein (1973)
Greenlandic (West)	Eskimo-Aleut	Greenland	Fortescue (1984)
Hittite	Indo-European	extinct	Kimball (1999)
Humburi Senni	Nilo-Saharan (Songhay)	Mali	Heath (1999)
Italian	Indo-European (Romance)	Italy	Tuttle (1997), Cordin (1997)
Japanese	isolate	Japan	Ito & Mester (1995)
Kashmiri	Indo-European (Indo-Iran.)	India	Wali & Koul (1997)
Kinyamwezi	Niger-Congo (Bantu)	Tanzania	Magana & Schadeberg (1992)
Korean	isolate	South Korea	Kim (2001)
Kosraean	Austronesian (Oceanic)	Caroline islands	Lee & Wang (1984)
Koyra Chiini	Nilo-Saharan (Songhay)	Mali	Heath (1999)
Lahu	Tibeto-Burman	Thailand	Matisoff (1982)
Latin	Indo-European (Italic)	extinct	Pope (1952), Sommer (1948)
Latvian	Indo-European (Baltic)	Latvia	Forssman (2001)
Maori	Austronesian (Oceanic)	New Zealand	Bauer (1993)
Mongo (Lomongo)	Niger-Congo (Bantu)	Congo	Spaandonck (1964)
Nadroga (Fijian)	Austronesian (Oceanic)	Fiji	Lynch, Ross & Crowley (2002)
Nauruan	Austronesian (Oceanic)	Nauru	Kayser (1993)
Nhanda	Australian	Australia	Blevins (2001)
Nishnaabemwin (Ojibwe)	Algic (Algonquian)	Canada (Ontario)	Valentine (2001)
Nyakyusa	Niger-Congo (Bantu)	Tanzania	Labroussi (1999)
Papago (O'odham)	Uto-Aztecan (Tempiman)	USA (Arizona)	Halle & Clements (1983)
Pima Bajo	Uto-Aztecan (Tempiman)	Mexico	Fernandez (1996)
Plains Cree	Algic (Algonquian)	Canada	Wolfart (1973)
Polish	Indo-European (Slavic)	Poland	Rubach (1994), Carlton (1990)
Quebec French	Indo-European (Romance)	Quebec	Cedegren et al. (1991)
Ririo	Austronesian (Oceanic)	Solomon Islands	Tryon & Hackman (1983)
Romanian	Indo-European (Romance)	Romania	Chitoran (2001)
Rundi	Niger-Congo (Bantu)	Burundi	Spandoonck (1964)
Runyoro-Rutooro	Niger-Congo (Bantu)	Uganda	Rubongoya (1999)
Samoan	Austronesian (Oceanic)	Western Samoa	Mosel & Hovdhaugen (1992)

Sanskrit	Indo-European (Indo-Aryan)	extinct	Misra (1967)
Sengga	Austronesian (Oceanic)	Solomon Islands	Tryon & Hackman (1983)
Serbo-Croatian	Indo-European (Slavic)	former Yugoslavia	Kordić (1997)
Shona	Niger-Congo (Bantu)	Zimbabwe	Brauner (1995)
Slovak	Indo-European (Slavic)	Slovakia	Carlton (1990)
Sonora Yaqui	Uto-Aztecan (Sonoran)	Mexico (Sonora)	Dedrick & Casad (1999)
Sorbian	Indo-European (Slavic)	Germany	Wowčerk (1954)
Southern Kongo	Niger-Congo (Bantu)	Angola	Halle & Clements (1983)
Taiof (Saposa)	Austronesian (Oceanic)	Papua New Guinea	Lynch, Ross & Crowley (2002)
Tawala	Austronesian (Oceanic)	Papua New Guinea	Ezard (1997)
Tümpisa Shoshone	Uto-Aztecan (Numic)	USA (California)	Dayley (1989)
Turkana	Nilo-Saharan	Kenya	Dimmendaal (1983)
Vaghua	Austronesian (Oceanic)	Solomon Islands	Tryon & Hackman (1983)
Varisi	Austronesian (Oceanic)	Solomon Islands	Tryon & Hackman (1983)
Wai Wai	Carib (Northern)	Brazil	Hawkins (1998)
West Futuna-Aniwa	Austronesian (Oceanic)	Vanuatu (Futuna Islands)	Dougherty (1983)
Woleaian	Austronesian (Oceanic)	Caroline islands	Tawerilmang & Sohn (1984)

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German glide formation functionally viewed*

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Abstract

Glide formation, a process whereby an underlying high front vowel is realized as a palatal glide, is shown to occur only in unstressed prevocalic position in German, and to be blocked by specific surface restrictions such as *ji and *ʁj. Traditional descriptions of glide formation (including derivational as well as Optimality theoretic approaches) refer to the syllable in order to capture its conditions. The present study illustrates that glide formation (plus the distribution of long and short tense /i/) in German can better be captured in a Functional Phonology account (Boersma 1998) which makes reference to stress instead of the syllable and thus overcomes problems of former approaches.

1 Introduction

The present study on glide formation is restricted to the palatal glide /j/. German has no phonemic labiovelar glide [w], but phonetically this segment occurs as second part of the falling diphthong [aw] as in *grau* 'grey'. Furthermore, some loanwords undergo a change of the form /u/ → [w], for instance *Guave* 'guava' [gu.ˈa.və] can be realized as [ˈgwa.və] in fast speech. Since these processes are restricted to loanwords with sequences of /gu/ plus vowel, they are extremely rare and will be ignored in the following discussion.[1]

The palatal glide in German is usually described as occurring in onset or coda position, as the examples in (1a) and (1b), respectively, illustrate (the IPA transcriptions are based on Muthmann 1996, with exceptions as elaborated in section 2 below). The glide does not occur in the syllable nucleus.

(1)	a)	Joch	[jɔx]	'yoke'	b)	drei	[dʁaj]	'three'
		Koje	[ˈkoː.jə]	'bunk'		heute	[ˈhɔj.tə]	'today'
		Banjo	[ˈban.jo]	'Banjo'		Zeitung	[ˈtsaj.tʊŋ]	'newspaper'

A syllabic high front tense vowel [i] in prevocalic position can be re-syllabified as the onset of a following syllable, and is then realized as a glide. Examples are given in (2).[2,3,4]

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1 The marginal status of the labio-velar approximant is reflected in the phonological dictionaries of German, which shows inconsistencies in the description of the possibly glided /u/: in Muthmann (1996), for instance, *Jaguar* 'jaguar' is listed with a glide (a non-syllabic vowel) [ˈjaːgu̯aːr], and *Pinguin* with a full vowel [ˈpɪŋguiːn].

2 In German, a glottal stop is optionally inserted before a syllable-initial, stressed vowel (Hall 1992: 58f.). It can also be inserted before an unstressed morpheme-initial vowel, though less often than before a stressed one (Vater 1995: 96). The glottal stop is not included in the present transcriptions, unless it is of importance for the analysis, see section 3.

3 The syllabification in these and the following examples is based on Hall (1992, 2003).

(2)	Tiara	‘tiara’	[ti.ˈɑː.ra]	~	[ˈtjɑː.ra]
	Linie	‘line’	[ˈliː.ni.ə]	~	[ˈliː.njə]
	Indien	‘India’	[ˈɪn.di.ən]	~	[ˈɪn.djən]
	Ferien	‘holidays’	[ˈfe.ʁi.ən]	~	[ˈfɛɐ.jən]
	grandios	‘terrific’	[gʁan.di.ˈɔs]	~	[gʁan.ˈdjɔs]
	Gremium	‘panel’	[ˈgʁe.mi.ʊm]	~	[ˈgʁe.mjʊm]

This optional process will be referred to as *glide formation* in the present article, following Hall (1992, 2003) for German, and Rosenthall (1994) for other languages.

Some German words can only be pronounced with a glide though their orthographic representation shows an <i>, see the examples in (3).

(3)	Nation	‘nation’	[na.ˈtsjoːn]	*[na.tsi.ˈoːn]
	Union	‘union’	[ʊ.ˈnjoːn]	*[ʊ.ni.ˈoːn]
	Familie	‘family’	[fa.ˈmiː.ljə]	*[fa.ˈmiː.li.ə]
	Flexion	‘inflexion’	[fle.ˈksjoːn]	*[fle.ksi.ˈoːn]
	Mission	‘mission’	[mi.ˈsjoːn]	*[mi.si.ˈoːn]
	Skorpion	‘scorpio’	[skɔɐ.ˈpjoːn]	*[skɔɐ.pi.ˈoːn]

Hall (1992: 169) points out that the glides in the words under (3) can be realized as vowels “but this is typically a spelling pronunciation”. Such words could be argued to have an underlying /i/ that undergoes glide formation, but since no related word forms exist with a vowel instead of the glide, the learner has no reason to assume anything else than an underlying glide (see section 2 for further arguments on the assumption of an underlying glide). The case is different for words like the ones in (4a). Though these are mainly pronounced with a glide, too, they have related forms that indicate a vowel – glide alternation, see (4b).

(4)	a) *word*		*gloss*	b) *related form*		*gloss*
	Studium	[ˈʃtuːdjʊm]	‘studies’	studieren	[ʃtʊ.ˈdiː.ʁən]	‘to study’
	Linie	[ˈliː.njə]	‘line’	liniiert	[liː.ni.ˈiːɐt]	‘ruled’
	Prämie	[ˈpʁe.mjə]	‘bonus’	prämieren	[pʁe.ˈmiː.ʁən]	‘to award’

Due to this vowel – glide alternation, the forms in (4a) are assumed to have an underlying high front vowel that undergoes glide formation. Evidence for an underlying vowel for both forms (3a and b) is given by the fact that a pronunciation of the words in (4a) with a high front vowel is acceptable, whereas the word forms in (4b) cannot be pronounced with a glide.

Derivational approaches to glide formation include Steriade’s (1984) treatment of Romanian, where she describes gliding as a rule that turns the vowel with the feature [+syllabic] into a glide with the feature [–syllabic]. Steriade’s approach depends on an identical underlying representation of the glide and the vowel, with high vocoids not being specified for major class features (which would make a categorization as either vowel or consonant necessary). Derivational work on gliding in German includes Hall (1992) and

4 The two different r-realizations of the word *Ferien* are based on Kohler (1995: 157). The respective surface restriction on *rj* sequences in German is discussed in section 4.3 below.

Wiese (1996). Both assume that the glide and vowel have the same feature representation but are assigned different skeletal positions or syllable constituents. A common problem of these derivational approaches is that several levels of syllabification have to be assumed: first reference to the syllable is necessary to capture the conditions for gliding. After gliding occurs, a resyllabification has to take place, since the glide is no longer vocalic, i.e. a syllable-nucleus.

Optimality-Theoretic approaches (Prince & Smolensky 1993; henceforth: OT) can avoid the problem of an application of the gliding rule followed by a resyllabification algorithm. Instead, syllabification and the realization of the single segment (vowel or glide) are evaluated simultaneously. Rosenthall (1994) proposes an OT account for vowel gliding in which he refers to the suprasegmental unit of the mora: a vowel /i/ is parsed as a non-moraic glide [j]. In their underlying form, the glide and the vowel do not differ. Hall's (2003) brief treatment of vowel gliding in German follows Rosenthall's approach.

In contrast to the OT approaches by Rosenthall and Hall, the account presented in this article assumes that the high front vowel and palatal glide differ in their underlying featural specification: the vowel is specified with a feature [+long] that implements its longer duration compared to the glide that is specified as [–long]. According to this view, glide formation involves a change from the underlyingly specified [+long] segment to a surface [–long] segment, licensed by constraints that militate against redundant articulatory effort. Blocking of such a change occurs when the segment in question is stressed, which is ensured by a high-ranked constraint that requires faithfulness to [+long] in stressed segments.

The present article is structured in the following way. Section 2 introduces controversies in the phonological representation and phonetic transcription of the high front vowel and the palatal glide in German. In section 3 the traditional OT account of glide formation with reference to the mora is described, and its shortcomings are illustrated. In section 4 I present an alternative account in a Functional Phonological framework that is based on the phonetic durational difference between vowel and glide. The last section concludes.

2 Of allophones and phonemes, and their transcription

In the phonological literature on German it is often argued that every instance of the palatal glide can be derived from an underlying high front vowel /i/ (see Wurzel 1970, Hall 1992, 2003, Wiese 1996).[5] This assumption is based on the fact that [i] and [j] are in complementary distribution; the glide occurs at the edges of the syllable, as illustrated in (1) above, whereas the vowel can occur in the syllable nucleus only. The allophonic view of the high front vocoids is problematic for the following reasons. Let us look at the two German words *Ion* 'ion' and *Joch* 'yoke'. The first one can be pronounced as either [i.ˈoːn] or [ˈjoːn] (though the latter only in very quick speech), the second only as [jɔx], not as *[i.ˈɔx]. If both of them were represented with an initial /i/, how could we account for the fact that this segment *has* to be glided in *Joch*, but can be optionally glided in *Ion*?[6] Additional representational information besides phonological features had to be included in order to make this distinction. The same

[5] Hall (1992: 134ff) and Wiese (1996: 237) actually assume an underlying lax vowel /ɪ/, from which all occurrences of the glide can be derived.

[6] The presently chosen examples are not ideal, since German seems to have a restriction on glide formation that requires a resulting minimal prosodic word of two syllables, since gliding in words such as *Ion*, *Diät*, or *Spion* sounds odd.

observation led van Lessen Kloeke (1982: 36ff.) and Werner (1972: 47) to assume an underlying differentiation between the high front vocoids.

Furthermore, German glide formation is blocked from applying if a sequence of palatal glide and high front vowel would result, e.g. the word *liniiert* ‘ruled’ is realized as [li.ni.ˈiːɐt] not *[li.ˈnjiːɐt]. Nevertheless, German words with *ji* sequences exist, for instance *injizieren* ‘to inject’ [in.ji.ˈtsiː.ʁən]. As Hall (2003: 100) correctly points out, occurrence of the latter can only be accounted for if the glide is assumed to be present underlyingly.[7] Glide formation, on the other hand, does not apply if a surface sequence *ji* would emerge, see also section 4.3 below. Based on these two arguments, the present article assumes an underlying difference between the high front vowel and the palatal glide. The exact nature of this featural difference is dealt with in section 4.1.

A further point for clarification in the topic of German vowel-glide alternations is the notation of the high front vocoids. Pronunciation dictionaries of German have the following conventions for the transcription of the glide /j/. For word- and syllable-initial instances, the symbol [j] is used, though mostly to denote a palatal fricative (a [j̞] in IPA notation), see for instance Muthmann (1996) and Mangold (2000). Glides in post-vocalic position, which form together with the preceding tautosyllabic vowel a diphthong (cf. 1b), are transcribed either as a plain [i] (Muthmann 1996), a shortened [i̯] (Mangold 2000 for <ei>), or even as [y] (Mangold 2000 for <eu>). The high front vowel that occurs in pre-vocalic position and might undergo glide formation is generally transcribed as [i̯], irrespective of whether glide formation is obligatory, as in *Spanien* [ˈʃpɑːni̯ən] ‘Spain’, or optional, as in *Spion* ‘spy’ [ʃpi̯oːn] (both Mangold 2000: 766 and 769, respectively). The same tradition can be found in the phonological literature on German, where a distinction is made between [i̯], an allophone of /i/ that underwent glide formation, and [j] or [j̞], which are used for the underlying glide (Hall 1992, Yu 1992: 107, Wiese 1996).

A common source of both the pronunciation dictionaries and the phonological descriptions for a surface distinction between underlying glides and vowels that underwent gliding is Moulton (1962: 65). He distinguishes [i̯] from [j] and gives the following examples (the transcription and indication of the stress in (5) is Moulton’s):[8]

(5) a)	[i̯]		b) [j]	
	[dɑ́ːli̯ə]	Dahlie	[táljə]	Taille
	[ʃpɑ́ni̯ər]	Spanier	[ʃampánjər]	Champagner
	[famíːli̯ə]	Familie	[vaníljə]	Vanille
	[bɪli̯óːn]	Billion	[bɪljét]	Billet
	[mɪli̯árdə]	Milliarde	[brɪljánt]	brillant

According to Moulton, the two realizations of the glide under (5) differ in their syllable-position: [j] occurs syllable-initial, and [i̯] as second member of an onset cluster. Obviously, this transcription is guided by spelling: those segments written with an <i> are represented as [i̯], whereas those that do not have an <i> in the orthography are represented as [j]. Neither Moulton nor the pronunciation dictionaries and phonological descriptions based on his work

7 Even though such words are marginal in German, as pointed out by T.A. Hall (p.c.), they make an underlying distinction between glide and vowel necessary.

8 Note that not all words in (5a) are examples for glided vowels: the glide in the forms [bɪli̯óːn] and [mɪli̯árdə] is assumed to be underlying in the present approach since no alternating forms of these words with a vowel exist.

give an explanation on the phonetic realization of [i̯], the so-called ‘non-syllabic vowel’, and on how it differs from the glide [j].

Based on the lack of phonetic evidence for a difference between the glided vowel and the underlying glide in German, the present study discards of the symbol [i̯] and transcribes all glides (independent of their syllable position) as [j], including the second part of the diphthongs [ɔj] and [aj]. Possible allophones of the glide such as the palatal fricatives [j̥] and [ç] which occur after voiced and voiceless obstruents, respectively (Kohler 1995: 156), are not differentiated. For an overview and discussion of these allophones see Mücke (1998).

The correlations between the phonemes /i/ and /j/ and their relevant allophones in the traditional approaches elaborated above and in the present view are summarized in figure 1.

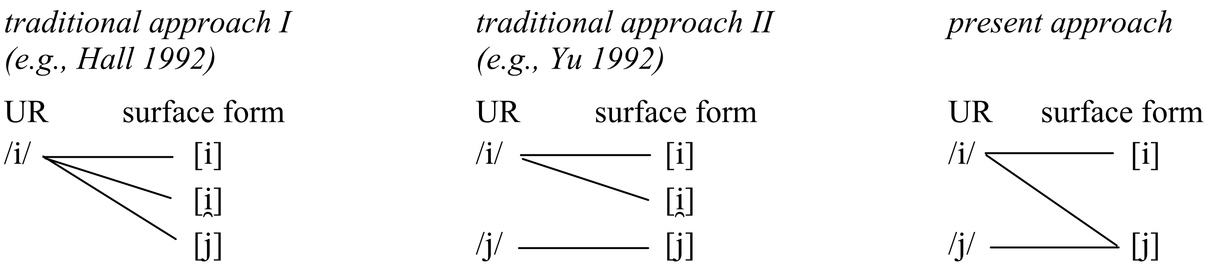

Figure 1 Three views on the phoneme /i/ and its glide allophone in relation to the phonetic realization of /j/.

In the proposal on the left of figure 1, made e.g. by Hall (1992) and Wiese (1996), a surface differentiation between vowel, glided vowel, and glide is made. All three stem from the same underlying high front vowel /i/. To determine the surface realization of the vowel, reference to its syllable-position is then necessary.

The second approach, represented by Yu (1992) and depicted in the middle of figure 1, assumes the same surface distinctions as the first proposal. However, these three surface forms are derived from two underlying representations: the surface glide stems from the underlying glide, whereas the vowel and glided vowel stem from the underlying vowel. Yu (1992: 109) proposes that the glided vowel and the underlying vowel have the same segmental features but are assigned different skeletal positions, with the glided vowel being dominated by a C and the unchanged vowel by a V, see figure 2.

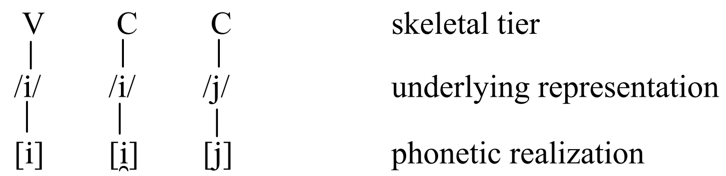

Figure 2 The three representations of vowel, glided vowel, and glide according to Yu (1992).

Two phonological tiers are thus necessary in Yu’s model to account for the surface contrasts of high vocoids in German.

The view taken in the present article (figure 1 right) is that of two underlying segments, glide and vowel, and of two surface realizations, either a vowel or a glide. As mentioned before, further allophones of the glide (such as [j̥] and [ç]) are not included, since they are not relevant for the present argumentation. In the context of glide formation, a neutralization of glide and vowel occurs. The advantage of the present approach, which discards of syllable-related distinctions between glide realizations, is illustrated in section 4 below.

3 A syllable-based OT account of vowel gliding

The two traditional OT approaches to vowel gliding discussed here, namely Rosenthall (1994) for a large number of languages and Hall (2003) for German, have one point in common with generative descriptions (such as Steriade 1984); they treat vowel glide alternations as 'a *result* of syllabification' (Rosenthall 1994: 8; italics mine). Both analyses refer to the mora to account for vowel gliding: whereas the underlying vowel is moraic, the surfacing glide is non-moraic. Two constraints are necessary for such an analysis, a faithfulness constraint MAX–μ, which preserves the underlying mora of the vowel (Itô 1986), cf. (6a), and a markedness constraint ONSET, which requires syllables to have onsets (Itô 1989, Prince & Smolensky 1993), cf. (6b). A change from vowel to glide is possible if one assumes that ONSET is higher ranked than MAX–μ, as in (6c).

(6) a) MAX–μ: "A mora in the input corresponds to a mora in the output."
b) ONSET: "Syllables have to have an onset."
c) ONSET » MAX–μ

The ranking in (6c) is proposed by Hall (2003) to account for glide formation in German. The word *Studium* is taken as example in tableau (7) to illustrate the analysis given by Hall:

(7)

/ˈʃtuːdiʊm/	ONSET	MAX–μ
[ˈʃtuː.di.ʊm]	*!	
☞ [ˈʃtuː.djʊm]		*

In this example, the second candidate, the one with the glide, wins because its second syllable has an onset (the glide). The first candidate has an onset-less second syllable and though it is most faithful to the underlying mora of the high vowel it loses due to its violation of the high-ranked ONSET constraint.

The tableau in (7) is missing an essential candidate, namely one with a glottal stop inserted between [ɪ] and [ʊ] (recall footnote 2 on the insertion of glottal stops in German). The candidate with a glottal stop is optimal with the present constraints, since it violates neither ONSET (all three syllables have an onset) nor MAX–μ (the vowel is not changed and thus the mora preserved). But as a new segment is inserted, this candidate would violate DEP (ʔ), which militates against the insertion of a glottal stop. Ranking DEP (ʔ) (or a general DEP) above MAX–μ secures the candidate with the glide to win, see (8).

(8)

/ʃtuːdiʊm/	ONSET	DEP (ʔ)	MAX–μ
[ˈʃtuː.di.ʊm]	*!		
☞ [ˈʃtuː.djʊm]			*
[ˈʃtuː.di.ʔʊm]		*!	

A candidate with a glottal stop therefore does not challenge the account proposed by Hall and Rosenthall.

However, there are problematic cases for the moraic OT approach. First, words like *naiv* ‘naive’ [na.iːf] with a stressed post-vocalic [i] are expected to undergo glide formation with the present constraints, since there is no constraint prohibiting a re-syllabification of the vowel as a coda, which is mora-preserving (though only one mora if an underlying long vowel is assumed). The candidate that should win is indicated by a ☹.

(9)

/naiːf/	ONSET	MAX–□
☹ [na.ˈiːf]	*!	
☞ [ˈnajf]		*

Second, words like *Zion* ‘zion’ [ˈtsi.ɔn] with a stressed pre-vocalic [i] are reduced to [ˈtsjoːn] with the present constraints, since these constraints are insensitive to stress assigment:[9]

(10)

/tsiːɔn/	ONSET	MAX–□
☹ [ˈtsiː.ɔn]	*!	
☞ [ˈtsjoːn]		*

As these two examples show, the syllable-based account allows gliding of stressed high vowels because it does not take into account whether the vowels are stressed or not. A solution to this problem cannot be easily integrated in this approach, since the constraints used (ONSET and MAX–□) are syllabification constraints, only, which do not refer to stress. In the following section, a functional OT account is introduced that includes information on stress-assignment and therefore can avoid the problems discussed here.

4 A Functional Phonological account

Before presenting an alternative analysis of glide formation, we have to first determine the underlying representations of high front vowels and glides in the present framework. This will be done in section 4.1 below. Section 4.2 then offers an OT analysis. Section 4.3 deals with phonotactic restrictions that influence glide formation in German and their inclusion in the analysis, and section 4.4 is concerned with the optionality of gliding.

4.1 Underlying specifications and necessary constraints

The present study employs Boersma’s (1998 and following) Functional Phonology model (henceforth: FP) to account for the process of glide formation in German. A main contribution of FP to phonological theory is its distinction between a production, a perception, and a recognition grammar. Since we are primarily concerned with the production of glides and vowels, we will focus here on the production grammar.[10] A further point of FP that strongly

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9 The change in vowel quality and vowel length is obligatory in German for word-final stressed vowels, see Hall (2002a, b), and Hall & Hamann (2003), the latter show that this also holds for loanwords. The reader is referred to these sources for a formalization of the change in an OT framework.

10 The listener’s task of reconstructing the surface glide as underlying vowel could be of further interest for glide formation. This process is guided by the lexical knowledge of the listener and can be modelled by Boersma’s *recognition grammar*.

departs from traditional phonological approaches is the assumption of underlying *perceptual* features instead of articulatorily ones. In order to establish a perceptual feature that can be used to distinguish between high front vowels and palatal glides in German, we have to look at the perceptual and acoustic cues distinguishing the two segmental classes.

Maddieson and Emmorey (1985) compared the formant frequencies of the palatal glide and the high front vowel in Amharic, Yoruba, and Zuni. They found that in all three languages the glide has a lower first formant frequency than the vowel, and conclude from this that the glide is produced with a narrower constriction than the vowel. However, the recordings leading to this result include tokens of /i/ in palatal glide context only (in the nonsense word *iji*). As will be elaborated in section 4.3, the glide and maybe also the vowel in *ji* or *ij* sequences are expected to be articulated in a different way than in isolation or in other contexts, namely more consonantal-like for the glide (i.e., as a fricative) and more vowel-like for /i/ (i.e., as a mid front vowel) in order to manifest a greater difference between the two segments (perceptual reinforcement). Thus, the comparison of the high front vowel and palatal glide in exactly this context cannot reliably prove a difference in articulation.

Chitoran (2002, 2003) investigated the phonetic difference between the high front vowel [i] and the glide [j] in Romanian, and measured segmental duration, friction duration after the plosive [b], and the formant values at the starting point of both segments. The duration of the friction phase from plosive into the high vocoids was expected to be longer for the glide, indicating a narrower constriction. However, no significant differences could be found. Furthermore, Chitoran expected to find significant differences in the formant values at the beginning of the two segments. She found that the second formant was higher in the vowel for two of her three speakers. This is however no indication for a more narrow constriction in case of the glide, on the contrary. Chitoran (2003: 3016) interprets the lower F2 values for the glides as a ‘target undershoot’, which means that the glide is articulated with even less constriction than the vowel. The results of her studies show that only the difference in duration is a reliable cue for differentiating the two segments. Catford (1988: 67) also mentions duration as the only difference between the two high vocoids in English, and defines the palatal glide [j] is an ‘ultra-short [i]’.

Data on the articulatory difference between palatal glide and high front vowel in German is scarce. Wängler’s (1961) x-ray tracings of German [iː] and [j] of one speaker show that the two segments are articulated almost identically. The palatal glide [j] has a minimally longer constriction, i.e. the tongue front is raised a bit further than for the [iː]. Mücke (1997: 36f.) found in her acoustic investigation of the German high vocoids that both [iː] and [j] are voiced and have no frication intervocalically, and that apart from a distinction in duration no other spectral differences could are present.

The present study takes the duration difference as the only reliable cue for differentiating between palatal glide and high front vowel in German. This difference of duration is represented as the abstract feature [long], with the vowel /iː/ being specified as [+long] and the glide /j/ as [–long], with otherwise identical features (the feature [long] is ternary, with the third value [0long] discussed below).

In the present approach the following phonetically based features are employed to distinguish German vowels: [low F1] and [mid F1] (standing for a low and mid first formant, respectively), and [low F2], [mid F2] and [high F2] (standing for a low, mid, and high second formant, respectively).[11] The specification of the German vowels with these features, based on

[11] The present account employs the features [low F1] and [mid F1] to account for the presence of more high and mid vowels than low vowels (vowel height is inversely related to the height of the first formant).

the average formant values of German vowels in Ramers (1988) and Heid et al. (1995), is given in (11).

(11)	iː/j	ɪ	yː	ʏ	uː	ʊ	eː	ɛ	ə	øː	œ	oː	ɔ	ɑː	a
[loF1]	+	+	+	+	+	+	–	–	–	+	+	–	–	–	–
[miF1]	–	+	–	+	–	+	+	+	+	+	–	+	–	–	–
[loF2]	–	–	–	–	+	+	–	–	–	–	–	+	+	+	–
[miF2]	–	–	+	+	–	–	–	+	+	+	+	–	–	+	+
[hiF2]	+	+	–	–	–	–	+	+	–	–	–	–	–	–	–

In the present analysis the long open-mid vowel [ɛː], which Hall (1992) and Wiese (1996) assume to be a phoneme of German, is not included. I follow Moulton (1962), Sanders (1972), and Kohler (1995) who consider this sound a mere spelling pronunciation. Furthermore, I assume that the low vowels /a/ and /ɑː/ differ not only in quality but also in quantity, see van Lessen Kloeke (1982).

In addition to the native phonemes in (11), German has the non-native vowels [i e y o ø]. These sounds differ from the respective long vowels exclusively in quantity. Since they occur in unstressed position only, whereas the long native vowels occur in stressed position, I assume that these non-native vowels are underlyingly identical to the long vowels, see Kohler (1999: 88). Their surface realization differs from the underlying specification in the feature long; the non-native tense vowels are [0long], i.e. of intermediate duration, as opposed to the long stressed vowels [+long] and the short glides [–long], see (12).

(12)	iː	i	j	yː	y	eː	e	oː	o	øː	ø
[long]	+	0	–	+	0	+	0	+	0	+	0

The ternary feature [long] introduced here is not to be confused with Chomsky & Halle's (1968) binary feature [long], which was used to distinguish between underlyingly long and short vowels, only.

Within the present framework, a change from a vowel to a glide thus involves a featural change from [+long] to [–long]. Such a change militates against a perceptual faithfulness constraint, which Boersma (1998: 176f.) formulates as follows:

(13) *REPLACE (*feature*: *value$_1$, value$_2$* / *condition* / *left-env_right-env*):

"Do not replace a specified value (*value$_1$*) on a perceptual tier (*feature*) with a different value (*value$_2$*), under a certain *condition* and in the environment *left-env* and *right-env*."

Boersma's *REPLACE constraint family is similar to McCarthy & Prince's (1995) IDENT constraints. What IDENT fails to capture, however, is the possibility of gradual changes in feature values, and the fact that a small change is better accepted (i.e. causes fewer constraint violations) than the deletion of a whole feature plus the insertion of a new one.

For vowel gliding with the proposed underlying representations, a *REPLACE (long: +, –) constraint, or more mnemonic *REPLACE (iː, j), is necessary, which militates against a change from [+long] to [–long]. A change from underlying long to short vowel militates against the constraint *REPLACE (long: +, 0) or short *REPLACE (iː, i). Furthermore, the faithfulness constraint *REPLACE (long: +, Ø) or short *REPLACE (iː, Ø) militates against the total deletion of the feature [long]. These three constraints are inherently ranked with respect to each other: Being faithful to a feature (though changing its feature value) is better than deleting the whole feature, therefore *REPLACE (iː, Ø) is ranked highest. The replacement of the feature value [+long] by [–long] is worse than its replacement by [0long], since the latter involves only one step along a scale of feature values, thus *REPLACE (iː, j) is higher ranked than *REPLACE (iː, i). The total ranking of these faithfulness constraints is given in (14).

(14) *REPLACE (iː, Ø) » *REPLACE (iː, j) » *REPLACE (iː, i)

As the present study is not concerned with the deletion of high front vowels, the high-ranked *REPLACE (iː, Ø) is not included in the following analysis.

The complementary distribution of the long high front vowel in stressed position and its short counterpart in unstressed position can be added to these faithfulness constraints via stress conditions. In general it can be stated that it is more important to be faithful to the percept of a segment in stressed position than in unstressed one.[12] For the faithfulness constraints *REPLACE (iː, j) and *REPLACE (iː, i) this looks as follows:

(15) a) *REPLACE (iː, j / stressed):
"Do not replace [+long] by [–long] when stressed."
b) *REPLACE (iː, j / unstressed):
"Do not replace [+long] by [–long] when unstressed."
c) *REPLACE (iː, i / stressed):
"Do not replace [+long] by [0long] when stressed."
d) *REPLACE (iː, i / unstressed):
"Do not replace [+long] by [0long] when unstressed."
e) *REPLACE (iː, j / stressed) » *REPLACE (iː, i / stressed) » *REPLACE (iː, j / unstressed) » *REPLACE (iː, i / unstressed)

The constraint in (15a), which militates against the gliding of a stressed vowel, has a counterpart constraint (15b), which militates against the gliding of an unstressed vowel. Similar constraints against the shortening of the long high vowel are given in (15c) and (15d). The ranking as in (15e) emerges, with the *REPLACE constraints for stressed positions being higher ranked than those for unstressed positions.

Besides these faithfulness constraints, specific markedness constraints are necessary to account for glide formation. The high front vowel /iː/ requires a specific position of the tongue to be held for a certain duration (around 140 ms for a stressed /iː/ in German, see Ramers 1988: 197f.). The respective unstressed vowel requires the same position of the tongue for a shorter duration, and for the palatal glide an even shorter duration of the same gesture is required (unfortunately, no comparative data on the length of these three segments in German could be found). Thus both the shortening of /iː/ in unstressed position and its gliding can be motivated by a reduction of articulatory effort. This can be formulated by constraints of the *HOLD family (Boersma 1998: 150), as defined in (16).

(16) *HOLD (*articulator*: *position*, *duration*):
"An *articulator* stays at its neutral position, i.e., it is not held in any non-neutral *position* for any positive *duration*."

12 The present analysis is only concerned with primary stress. It has to be tested in future work whether the constraint in (15) refers to secondary stress, too. Words like *Biologe* 'biologist' [ˌbi.ɔ.ˈloː.gə], with secondary stress on the first syllable, seem to allow gliding in fast speech: [ˌbjɔ.ˈloː.gə], which indicates that gliding is not blocked by secondary stress.

To account for the articulation of a high front vowel a *HOLD (tongue: raised pre-dorsum, 140ms) constraint or short *HOLD (iː) is necessary. Similar *HOLD (i) and *HOLD (j) are needed. Since holding a gesture for 140 ms involves more effort than holding the same gesture for approximately 80 ms and 40 ms, respectively, the three constraints are universally ranked as in (17).

(17) *HOLD (iː) » *HOLD (i) » *HOLD (j)

The low ranked *HOLD (j) is irrelevant in the following analysis, and therefore not included. Since any change of the high front vowel /iː/ in *stressed* position is not allowed in German, *HOLD (iː) has to be ranked below the faithfulness constraints for the stressed vowel, see (18).

(18) *REPLACE (iː, j / stressed) » *REPLACE (iː, i / stressed) » *HOLD (iː) » *REPLACE (iː, j / unstressed) » *REPLACE (iː, i / unstressed)

In languages that do not allow *any* shortening or gliding of long high front vowels (whether stressed or unstressed), the *HOLD (iː) constraint is ranked below *REPLACE (iː, j / unstressed) or *REPLACE (iː, i / unstressed), respectively.

4.2 Analysis

With the constraints and the underlying specifications as elaborated in section 4.1, the gliding of the high front vowel in German can be formalized in a FP production grammar as in tableau (21). Before looking at this tableau in detail, some shorthand conventions have to be elaborated. In a FP production grammar, the input is the lexically stored perceptual representation of the word in question. This is represented in pipes |*spec*|. The output candidates that this form is compared to consist of two forms each, namely an articulatory and a corresponding perceptual form. The articulatory output is given in brackets [*art*] and the corresponding perceptual output in slashes /*perc*/, all following Boersma (1998: 143ff.). Since a detailed transcription of both output forms is not necessary and might be confusing, we transcribe both forms in IPA notation. The reader has to be aware that the articulatory markedness constraints (e.g. *HOLD (iː)) tackle the articulatory form [*art*], whereas the perceptual faithfulness constraints (e.g. *REPLACE (iː, j)) refer to the corresponding perceptual form /*perc*/.

The main stress of a lexical item is assumed to be underlyingly specified if it is irregular, and assigned via stress-specific constraints if regular. Since the present article is not concerned with stress-assignment in German, the reader is referred to Féry (1998) for an OT treatment of this topic and the relevant constraints. For simplicity, stress is indicated in the underlying specifications on the respective vowel.

First, the realization of the stressed long /iː/ with the present constraints is illustrated with the word *sie* 'they' [ziː], see tableau (19).

(19)

|zˈiː|	*REPLACE (iː, j / stressed)	*REPLACE (iː, i / stressed)	*HOLD (iː)	*REPLACE (iː, j / unstressed)
[ˈzi] /ˈzi/		*!		
☞ [ˈziː] /ˈziː/			*	
[ˈzj] /ˈzj/	*!			

Tableau (19) illustrates that neither shortening nor gliding of the *stressed* high front vowel is acceptable in German. Thus, the problematic cases for the syllabic OT account, namely *naiv* and *Zion*, can be accounted for in the present proposal. Note that function words such as *sie* can undergo vowel shortening in unstressed position, because then they do not violate the *REPLACE (iː, i / stressed) constraint.

Next, the shortening of the high front vowel in unstressed position has to be dealt with. This is done in tableau (20) with the example *Titan* 'titan' /tiːˈtɑːn/. As the constraints on the stressed high vowel are not relevant for this and the following examples, they are not included.

(20)

|tiːtˈɑːn|	*HOLD (iː)	*REPLACE (iː, j / unstressed)	*HOLD (i)	*REPLACE (iː, i / unstressed)
[tiː.ˈtɑːn] /tiː.ˈtɑːn/	*!			
☞ [ti.ˈtɑːn] /ti.ˈtɑːn/			*	*
[tj.ˈtɑːn] /tj.ˈtɑːn/		*!		

The ranking of the two constraints *HOLD (i) and *REPLACE (iː, i / unstressed) cannot be determined on the basis of this data.

With the constraints as defined up to now, however, the process of vowel gliding is predicted not to occur, as the example *Studium* in tableau (21) shows.

(21)

|ʃtˈuːdiːʊm|	*HOLD (iː)	*REPLACE (iː, j / unstressed)	*HOLD (i)	*REPLACE (iː, i / unstressed)
[ˈʃtuː.diː.ʊm] /ˈʃtuː.diː.ʊm/	*!			
☞ [ˈʃtuː.di.ʊm] /ˈʃtuː.di.ʊm/			*	*
☹ [ˈʃtuː.djʊm] /ˈʃtuː.djʊm/		*!		

This ranking is problematic since *HOLD (i) is ranked below *REPLACE (iː, j / unstressed) which never allows any vowel gliding, but tableau (20) showed that exactly this ranking is necessary to block gliding of the unstressed vowel in words as *Titan*. What the FP constraints as defined up to now do not take into consideration is that gliding only takes place if another vowel is adjacent to the high front vowel, i.e. the environment of gliding is pre-vocalically (and possibly also post-vocalically).[13] Thus words like *Studium* can undergo gliding whereas words like *Titan* cannot. Since the perceptual faithfulness constraint *REPLACE can include specific conditions, recall its definition in (13), the necessity for an adjacent vowel can be added to *REPLACE (iː, j / unstressed) as in (22a).

(22) a) *REPLACE (iː, j / unstressed / C_C):
"Do not replace [+long] by [–long] interconsonantally."
b) *REPLACE (iː, j / unstressed / C_C) » *REPLACE (iː, j / unstressed)
c) *HOLD (iː) » *REPLACE (iː, j / unstressed / C_C) » *HOLD (i) » *REPLACE (iː, j / unstressed) » *REPLACE (iː, i / unstressed)

According to the elsewhere condition (Kiparsky 1973), the more restricted constraint in (22a) has to be ranked above the general constraint *REPLACE (iː, j / unstressed) introduced above,

13 Though not discussed in the phonological literature on German, optional gliding of post-vocalic high front vowels (i.e. formation of a falling diphthong) applies, too. The word *Koitus* 'coitus' [ˈkoː.i.tʊs], for instance, is acceptable with a realization as [ˈkɔj.tʊs] in quick speech, and so is the first name *Alois* [ˈaː.lɔ.is] ~ [ˈaː.lɔjs]. The fact that gliding can apply both to pre- and post-consonantal vowels, i.e. to onsets and codas, is a strong argument against the syllabic account presented in section 3.

as in (22b). Furthermore, the *HOLD (i) constraint is ranked below *REPLACE (iː, j / C_C) because a reverse ranking gave vowel gliding even for interconsonantal /iː/. This results in the ranking in (22c).

With this modification of the *REPLACE constraints, both examples like *Studium* and *Titan* can be accounted for:

(23)

|ʃtˈuːdiːʊm|	*HOLD (iː)	*REPLACE (iː, j / unstressed / C_C)	*HOLD (i)	*REPLACE (iː, j / unstressed)	*REPLACE (iː, i / unstressed)
[ˈʃtuː.diː.ʊm]/ˈʃtuː.diː.ʊm/	*!				
[ˈʃtuː.di.ʊm] /ˈʃtuː.di.ʊm/			*!		*
☞ [ˈʃtuː.djʊm]/ˈʃtuː.djʊm/				*	

(24)

|tiːtˈɑːn|	*HOLD (iː)	*REPLACE (iː, j / unstressed / C_C)	*HOLD (i)	*REPLACE (iː, j / unstressed)	*REPLACE (iː, i / unstressed)
[tiː.ˈtaːn] /tiː.ˈtaːn/	*!				
☞ [ti.ˈtaːn] /ti.ˈtaːn/			*		*
[tj.ˈtaːn] /tj.ˈtaːn/		*!		*	

In contrast to the traditional OT approach, where the insertion of a glottal stop satisfies the ONSET constraint and thus inclusion of an additional constraint (*DEP) is necessary to rule out a candidate with a glottal stop (that would otherwise be optimal), the present approach needs only the high-ranked constraint *HOLD (iː) to ban *any* candidate with a fully realized vowel (with or without glottal stop).

It has to be mentioned here that vowel gliding is not restricted to high front vowels, or high vowels. As has been shown by Rosenthall (1994), languages such as Ilokano and Logo have a gliding process for mid vowels in addition to that of high vowels. German has some words that allow gliding of the mid front vowel [e] under the same conditions as elaborated above for the high front vowels, namely in unstressed position and adjacent to another vowel. Examples are *Lineal* 'ruler' [li.ne.ˈaːl], realized as [li.ˈnjaːl] in colloquial German, and *ideal* 'ideal' [i.de.ˈaːl], also realized as [i.ˈdjaːl]. The presented account can be transferred to gliding of the mid front vowel: this process is motivated by the articulatory markedness constraint *HOLD (e), which has to be higher ranked than *HOLD (j) in German to account for the glide output of the mid front vowel gliding.

4.3 Surface restrictions

Vowel gliding is blocked in two instances where specific surface restrictions in German would be violated. The first one involves words such as *Natrium* 'sodium', *Patriarch* 'patriarch', and *Triumph* 'triumph', where glide formation would yield a (tautosyllabic) sequence of (stop plus) *r* plus glide.

In a syllable-oriented OT approach such as Hall (2003), the non-gliding of these words can be captured by a phonotactic constraint *▯[rj that prohibits a sequence of (consonant plus) *r* plus *j* in onset position. See Hall (2002a) who proposes this constraint to account for a phonotactic restriction in English, and Hall (1992: 171), who observes that *rj* sequences in German must be tautosyllabic. The constraints and their ranking necessary for a word such as *Natrium* not to undergo vowel gliding in a moraic OT account are given in tableau (25).

(25)

/nˈatrium/	*$_{□}$[rj	ONSET	MAX–□
☞ [ˈna.tri.um]		*	
[ˈna.trjum]	*!		*

In a functional, phonetically oriented approach, the restriction on the *rj* sequence does not have to refer to the syllable position, but can be formulated as a pure co-articulation restriction. It is impossible to pronounce a sequence of a velar fricative plus palatal glide, due to their different tongue configurations: the palatal glide involves a raising of the tongue front and a fronting of the tongue back, whereas the velar fricative involves a low tongue front and a retracted tongue back (see Hamann 2003 for a similar explanation for the co-occurrence restrictions on retroflex plus glide and retroflex plus front high vowel).[14] The constraint in (26) is a formalization of this:

(26) *[ʁj]: "A sequence of velar fricative and glide is not pronounceable."

Instead of the orthographic *r* that refers to any rhotic realization in German, the present constraint refers particularly to a velar fricative.[15] The constraint in (26) is high-ranked in German. It is not necessary to refer to the syllable as domain for this constraint, since German does not have a [ʁj] sequence across syllable boundaries: the *r* sound is realized as a vocalic [ɐ] in coda position. The two possibilities of *r*-realization and syllabification (recall footnote 4) are illustrated with the first and third candidate of the word *Bakterie* 'bacterium' in tableau (27).

(27)

|baktˈeʁiːə|	*[ʁj]	*HOLD (iː)	*REPLACE (iː, j / unstressed / C_C)	*HOLD (i)	*REPLACE (iː, j / unstressed)
[bak.ˈte.ʁiː.ə] /bak.ˈte.ʁiː.ə/		*!			
[bak.ˈte.ʁi.ə] /bak.ˈte.ʁi.ə/				*!	
[bak.ˈte.ʁjə] /bak.ˈte.ʁjə/	*!				
☞ [bak.ˈteɐ.jə] /bak.ˈteɐ.jə/					*

In the first candidate in (27), no glide formation applies, thus no *rj* sequence emerges. In the second candidate, the vowel is not glided but shortened, and thus militates against the *HOLD (i) constraint. Glides are formed in the third and fourth candidates, but whereas the third results in a [ʁj] sequence and thus violates the high ranked *[ʁj], the last candidate only violates the low ranked *REPLACE constraint. The last candidate realizes the underlying velar

[14] Hall (2000b) gives a similar articulatory grounding for the non-occurrence of coronal rhotic plus palatal glide sequences.

[15] The present account ignores variants of the velar fricative such as the velar trill, and variants of Standard German that have an apical trill instead of a velar rhotic. An articulatory restriction similar to (26) could account for such varieties.

fricative /ʁ/ as vowel [ɐ], which is a regular process in coda-position in German. The constraints accounting for this process are not included in the present analysis.

The second case of vowel gliding where an additional restriction is required concerns words which would result in a surface *ji* sequence, recall the discussions in section 2. An example is the word *liniiert* ‘ruled’ [li.ni.ˈiːɐt] which does not undergo vowel gliding, *[li.ˈnjiːɐt]. To account for the blocking of glide formation if a [ji] sequence is to surface, we have to employ a constraint that is based on the fact that the two segments [iː] and [j] next to each other cannot be perceptually distinguished, since they are articulated in the same way and differ in length, only. Hall (2003) proposes a similar co-occurrence restriction. The presented constraint, see (28), does not only hold for long high front vowel plus glide but for any combination of high front vocoids.

(28) *[jiː/ iiː/ iːiː]: “A sequence of two high front vocoids cannot be perceptually parsed as such.”

Typological evidence for the constraint in (28), namely for the avoidance of palatal glide plus high front vowel sequences, comes from a large number of languages, for instance West Greenlandic (Fortescue 1984: 338) and Yucuna Ainu (Schauer & Schauer 1967), which have no surface [ji] sequences. For an overview of languages and an elaboration of the phonetic explanation see Kawasaki (1982) (which deals also with the similarly motivated avoidance of [wu] sequences).

The constraint in (28) can be considered a kind of OCP restriction (Goldsmith 1976), because it militates against the surfacing of adjacent segments that are identical apart from their length specification. This constraint holds for *ii* sequences, too. German, however, seems to allow such sequences, as in the word *liniiert*. It is reasonable to assume that German speakers insert a glottal stop between the first and the second [i], in this and similar words, since the latter is stressed (recall footnote 2). The candidate [li.ni.ˈʔiːɐt], with the inserted glottal stop therefore does not violate the *[jiː/ iiː/ iːiː] constraint, as illustrated in tableau (29). (This tableau does not contain the constraint *Replace (iː, j / unstressed / C_C)).

(29)

|liːniːˈiːɐt|	*Hold (iː)	*[jiː/ iiː/ iːiː]	*Hold (i)	*Replace (iː, j / unstressed)
[liː.niː.ˈiːɐt] /liː.niː.ˈiːɐt/	*!*	*		
[li.ni.ˈiːɐt] /li.ni.ˈiːɐt/		*!	**	
☞ [li.ni.ˈʔiːɐt] /li.ni.ˈʔiːɐt/			**	
[li.ˈnjiːɐt] /li.ˈnjiːɐt/		*!		

The ranking between *[jiː/ iiː/ iːiː] and *Hold (iː) cannot be decided on the basis of these data. The tableau in (29) does not contain a faithfulness constraint against the insertion of the glottal stop (*Replace (Ø, ʔ), which has to be ranked somewhere below the surface constraint *[jiː/ iiː/ iːiː] (its exact ranking cannot be decided on the basis of the present data alone).

Muthmann (1996: 331) lists an alternative pronunciation to *liniiert* [li.ni.ˈiːɐt] (the glottal stop is not specified in this source), namely one with only one *i*: [li.nˈiːɐt]. This candidate fairs even better than the winning one in tableau (29). It violates neither the *[jiː/ iiː/ iːiː] constraint nor the *Hold (i) constraint, because the unstressed [i] is dropped.

Despite the *[jiː/ iiː/ iːiː] constraint, German seems to allow homorganic glide-vowel sequences in words such as *injizieren* 'to inject' [in.ji.ˈtsiː.ʁən] or *Jieper* 'craving' [ˈjiː.pɐ], where this sequence is specified underlyingly. I assume that speakers, in order to make the *ji* sequence perceivable, produce a fricative instead of the glide to distinguish it from the vowel, thus produce the sequence [ʝi] (this assumption still has to be phonetically tested). Evidence for such an assumption is given by Laver (1994: 298) who remarks that the articulatory starting point for [j] in *ji* sequences of English and the Chentu dialect of Chinese is normally slightly closer and fronter than for [i]. "The approximants in these positions in English and Chinese can thus act as auditorily distinctive syllable-onsets to the following vocoids" (Laver 1994: 299). Further evidence comes from the Melanesian language Tinrin, which is spoken in the southern part of New Caledonia. In Tinrin, the glide /j/ is realized as a voiced palatal approximant, according to Osumi (1995: 19). Osumi (ibid.) further notes that "when it [the glide] occurs before front vowels, it is pronounced with greater friction." A similar observation was made for Lahu, a Tibeto-Burman language (Matisoff 1982).

The fricative articulation of the palatal glide in *ji* sequences can be modelled in an FP OT tableau as in (30), with a faithfulness constraint against the replacement of the glide by a fricative, *REPLACE (j, ʝ), being lower ranked than the surface restriction *[jiː/ iiː/ iːiː]:

(30)

|ˈjiː.pɐ|	*[jiː/ iiː/ iːiː]	*REPLACE (j, ʝ)	*HOLD (iː)	*HOLD (i)
[ˈjiː.pɐ] /ˈjiː.pɐ/	*!		*	
☞ [ˈʝiː.pɐ] /ˈʝiː.pɐ/		*	*	
[ˈji.pɐ] /ˈji.pɐ/	*!			*

This tableau shows that the perceptual markedness constraint *[jiː/ iiː/ iːiː] must be ranked above the perceptual faithfulness constraint *REPLACE (j, ʝ) and the articulatory markedness constraint *HOLD (iː). The exact location of *REPLACE (j, ʝ), however, cannot be determined with the present data.

4.4 Optionality

Up to now, nothing has been said in the analysis about the optionality of glide formation: the words under (2) were shown to be realizable either with glide or vowel. What happens then, if a speaker switches from a vowel realization to a glide realization, which usually goes together with a less formal register? In OT terms, such variability can be formalized as a reranking of constraints. In formal situations the *HOLD constraint hierarchy from (17) is demoted below the faithfulness constraint *REPLACE (iː, j / unstressed), see (31), because a faithful pronunciation is more important than saving articulatory effort. Note that *HOLD (i) has to stay ranked above the *REPLACE (iː, i / unstressed) constraint since vowel shortening in unstressed position is obligatory.

(31)

|ˈɪndiːən|	*REPLACE (iː, j / unstressed / C_C)	*REPLACE (iː, j / unstressed)	*HOLD (iː)	*HOLD (i)	*REPLACE (iː, i / unstressed)
[ˈɪn.diː.ən] /ˈɪn.diː.ən/			*!		
☞ [ˈɪn.di.ən] /ˈɪn.di.ən/				*	*
[ˈɪn.djən] /ˈɪn.djən/		*!			

In informal situations the *HOLD constraint hierarchy is promoted above the faithfulness constraints, see (32).

(32)

|ˈɪndiːən|	*HOLD (iː)	*HOLD (i)	*REPLACE (iː, j / unstressed / C_C)	*REPLACE (iː, j / unstressed)	*REPLACE (iː, i / unstressed)
[ˈɪn.diː.ən] /ˈɪn.diː.ən/	*!				
[ˈɪn.di.ən] /ˈɪn.di.ən/		*!			*
☞ [ˈɪn.djən] /ˈɪn.djən/				*	

5 Conclusion

The present study showed that glide formation depends not on the syllable-position but on the stress-conditions of the glided vowel: gliding cannot occur with stressed vowels. This was illustrated to be problematic for OT approaches such as Rosenthall (1994) and Hall (2003) which employ only syllable-building constraints for glide formation. The OT FP account with underlying perceptual representations proposed here can avoid these problems by incorporating stress information directly in its perceptual faithfulness constraints: simply put, the percept of a stressed vowel is not allowed to be changed, whereas the percept of an unstressed vowel can be changed (at least slightly). The respective faithfulness constraints (*REPLACE (iː, j / stressed) and *REPLACE (iː, j / unstressed)), have a phonetically grounded fixed ranking (see (15e)). So do the markedness constraints (*HOLD) that motivate gliding, see (17). Different rankings between these two hierarchies can account for the optionality of vowel gliding.

In addition to optional glide formation, the same constraints can represent the obligatory process of high front vowel shortening, which is also not dependent on the syllable position but on stress: it only occurs in unstressed position.

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