Voicing and continuancy in Catalan

A nonvacuous Duke-of-York gambit
and
a Richness-of-the-Base paradox

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23 November 2001

Please cite as:
Bermúdez-Otero, Ricardo (2001). "Voicing and continuancy in Catalan: a nonvacuous Duke-of-York gambit and a Richness-of-the-Base paradox." Ms., University of Manchester. Available online at www.bermudez-otero.com/Catalan.pdf

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3
Voicing and continuancy in Catalan obstruents: an interleaved analysis

3.1. Postlexical spirantization

Standard Catalan possesses the following set of distinctive consonantal segments; see Wheeler (1979: xxii, 222, 234, chs V and VI), Recasens (1991: 173), and Hualde (1992: §3.1.1).

(3.1) **Distinctive consonantal segments of Catalan**[1]

p		t				k
b		d				g
			(ts)	(tʃ)		
			(dz)	(dʒ)		
	f		s	ʃ		
			z	ʒ		
m			n		ɲ	
			l		ʎ	
			ɾ			
			r			
(w)					(j)	

Like Spanish, the language has three nonsibilant voiced obstruent phonemes, one for each of the major oral articulators: labial, coronal, and dorsal. These phonemes are represented in the chart as /b, d, g/. Each exhibits three allophones: a voiced continuant, a voiced noncontinuant, and a voiceless noncontinuant.

1 This chart has been adapted from Hualde (1992: 367). Brackets indicate items whose status as phonemes or as single segments is disputed.

(3.2) **Allophones of the nonsibilant voiced obstruent phonemes**[2]

	Lab	Cor	Dor
[+voi, +cont]	β	ð	ɣ
[+voi, -cont]	b	d̪	g
[-voi, -cont]	p	t̪	k

The voiceless allophones arise through a regular process of devoicing, whilst [b, d, g] also occur as contextual variants of the voiceless phonemes /p, t, k/ —as we shall see below, Catalan obstruents undergo voicing neutralization in both directions. For the moment, however, I shall leave the devoiced realizations aside and focus on the voiced allophones.

The distribution of [β, ð, ɣ] and [b, d, g] is controlled by a rule known as 'spirantization'. The name reflects the traditional assumption that the voiced noncontinuant series is basic (see e.g. Wheeler 1979: 316); the choice of symbols in chart (3.1) conforms with this assumption.[3] With two important provisos to be discussed below, the effects of spirantization can be summarized as follows (Wheeler 1979: 316-321; Mascaró 1984: 288-289; Recasens 1991: 182-193, 207-223, 234-243; Hualde 1992: 368-369):

(3.3) **Spirantization**

A nonstrident voiced obstruent is realized as a stop

- after pause[4]
- after an oral stop
- after a nasal
- if coronal, after a lateral
- if labial, after a labial fricative;

elsewhere, it is realized as a continuant.

In the following examples, largely garnered from the sources just mentioned, the relevant segments are highlighted in boldface:

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[2] The continuant allophones are phonetically realized as frictionless approximants, i.e. [β̞, ð̞, ɰ], rather than as fricatives; see Recasens (1991: 172, 181, 206, 234), Hualde (1992: 368). This is also the case for their Spanish analogues (Ladefoged 1993: 162; Baković 1994).

Note that, henceforth, I shall as a general rule dispense with the dentality diacritic of [d̪] and [t̪], unless a specific point involving place of articulation is at stake.

[3] Mascaró (1984: 292) suggests that the nonsibilant voiced obstruents of Catalan are underlyingly unspecified for continuancy. In the case of Spanish, Harris (1969) assumes that the stops are basic; Lozano (1979) and Baković (1994) propound dissenting views.

[4] Or initially in the 'breath-group'; see Macpherson (1975), quoted by Baković (1994).

(3.4) (a)	After pause		
	Basta!	[**b**astə]	‘Enough!’
	Déu meu!	[**d**ew mew]	‘Good God!’
	Guaita!	[**g**wajtə]	‘Look!’
(b)	After an oral stop[5]		
	advent	[əb**b**en]	‘advent’
	amic bo	[əmig **b**ɔ]	‘good friend’
	Obdúlia	[ub**d**uliə]	female name
	amic dolent	[əmig **d**ulen]	‘bad friend’
	cap gos	[kab **g**os]	‘no dog’
(c)	After a nasal		
	canvi	[kam**b**i]	‘change’
	un botó	[um **b**uto]	‘a button’
	any vinent	[aɲ **b**inen]	‘next year’
	banc bo	[baŋ **b**ɔ]	‘good bench’
	senda	[sɛn̪**d̪**ə]	‘path’
	un dia	[un̪ **d̪**iə]	‘a day’
	som dolents	[som **d̪**ulens]	‘we are bad’
	any dolent	[aɲ **d̪**ulen]	‘bad year’
	banc dur	[baŋ **d̪**u]	‘hard bench’
	sangonós	[səŋ**g**unos]	‘bloody’
	un gos	[uŋ **g**os]	‘a dog’
	som grans	[som **g**ɾans]	‘we are big’
	any gloriós	[aɲ **g**luɾios]	‘glorious year’
(d)	After a lateral		
	balda	[bal̪**d̪**ə]	‘latch’
	el dia	[əl̪ **d̪**iə]	‘the day’
	ell diu	[eʎ **d̪**iw]	‘he says’
	but		
	estalvis	[əstal**β**is]	‘savings’
	el botó	[əl **β**uto]	‘the button’
	ell va	[eʎ **β**a]	‘he goes’

[5] The preceding stop is always voiced, as it is lodged in the coda, where it undergoes postlexical voicing assimilation; see §x.x.x and §x.x.x.

colgar	[kul**ɣ**a]	‘to bury’
el gos	[əl **ɣ**os]	‘the dog’
ell guanya	[eʎ **ɣ**waɲə]	‘he wins’

(e) After a labial fricative[6]

buf brusc	[buv **b**ɾusk]	‘brusque puff’

but

buf diari	[buv **ð**iaɾi]	‘daily puff’
afgà	[əv**ɣ**a]	‘Afghan’
xef gallard	[ʃɛv **ɣ**əʎart]	‘dashing chef’

(f) Elsewhere[7]

anava	[əna**β**ə]	‘he went’ imperf.
la vaca	[lə **β**akə]	‘the cow’
esbós	[əz**β**os]	‘draft’
és blau	[ez **β**law]	‘is blue’
carbó	[kər**β**o]	‘coal’
mar bonic	[mar **β**unik]	‘pretty sea’
roda	[rɔ**ð**ə]	‘wheel’
la dona	[lə **ð**ɔnə]	‘the woman’
esdevenir	[əz**ð**əβəni]	‘to become’
és dur	[ez **ð**u]	‘is hard’
corda	[kɔr**ð**ə]	‘rope’
or diví	[ɔr **ð**iβi]	‘divine gold’

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6 In effect, [v] is the only labial fricative that can occur before a voiced obstruent. As we shall see below (§x.x.x), [β] is excluded because no member of the [β, ð, ɣ] series is ever found in the coda. This leaves only /f/, whose realization will be voiced in this position owing to voicing assimilation.

7 Bruguera i Talleda (1990), who purports to record a standard style of pronunciation centred on Barcelona, differs from the rest of my sources in consistently transcribing noncontinuant allophones after continuant consonants such as [z] and [r]: e.g. *esbós* [əz**b**ós], *carbó* [kər**b**ó], *esdevenir* [əz**d**əβəní], *corda* [kɔ́r**d**ə], *desglaçar* [dəz**g**ləsá], *amarga* [əmár**g**ə]. This may reflect a slight difference in the dialectal or stylistic basis of his pronunciation model. Nonetheless, Recasens (1991: 193, 221-222, 242-243) suggests that, as a general rule, those Catalan dialects with spirantization in intervocalic position also have it after fricatives and rhotics (except, of course, for the cluster [vb]).

amiga	[əmiɣə]	‘friend’ fem.
la gloria	[lə ɣlɔɾiə]	‘the glory’
desglaçar	[dəzɣləsa]	‘to defrost’
és groc	[ez ɣɾɔk]	‘is yellow’
amarga	[əmarɣə]	‘bitter’ fem.
mar gris	[mar ɣɾis]	‘grey sea’

As these examples make clear, the continuancy values of nonstrident voiced obstruents are entirely predictable on the surface. In compliance with Richness of the Base, therefore, the underlying representation of these segments must be rich in continuancy specifications; in other words, the analysis of spirantization must not depend on a particular value of [cont] being specified in the lexicon. Following the proposals made in section x.x.x, I shall henceforth notate the underlying voiced nonsibilant obstruents of Catalan as /𝔹, 𝔻, 𝔾/. The interpretation of these symbols is laid out in (3.5), subject to further refinements to be made in section x.x.x.

(3.5) /𝔹/ = { B, b, β }

/𝔻/ = { D, d, ð }

/𝔾/ = { G, g, ɣ }

In this notation, /𝔹akə/ stands for a class of equivalent underlying representations comprising /Bakə/, where the initial segment is unspecified for continuancy, alongside /bakə/ and /βakə/. The equivalence between these representations lies in the fact that all three will yield the same set of output forms. Of course, not all three are expected to occur in the speaker's mental dictionary; rather, Lexicon Optimization will select as optimal that underlying representation which produces the correct set of surface forms with the least serious violations of the constraint hierarchy (§x.x.x).

The evidence of (3.4) also shows that spirantization applies normally across word boundaries. It follows that, in an interleaved analysis, spirantization must be active at the postlexical level. Moreover, there are no lexical exceptions nor instances of misapplication associated with morpheme boundaries, and so one can safely conclude that spirantization does not apply at higher grammatical levels. This, however, has important consequences for the interplay between spirantization and Richness of the Base. Although voiced nonsibilant obstruents are underlyingly rich in continuancy specifications, the input to spirantization itself is nonrich: each segment has its continuancy value determined as either [+], [-] or [0] in its pass through the stem and the word levels. Thus, although underlying representations have /𝔹, 𝔻, 𝔾/, the output of the stem and word levels can only contain either [B, D, G], or [b, d, g], or [β, ð, ɣ] in any one position. As we shall see below (§x.x.x), the operation of word-level devoicing enables us to conclude on independent grounds that underlying /𝔹, 𝔻, 𝔾/ are mapped onto stem-level [b, d, g], so that the input to postlexical spirantization consists of stops. To a certain extent, this result will confirm the traditional opinion that the voiced stops are basic, insofar as [β, ð, ɣ] are derived from [b, d, g]. However, the analytical points which I will make in the paragraphs immediately following are not affected by this fact.

As suggested by the 'elsewhere' clause in (3.3), of the two allophonic series [b, d, g] and [β, ð, ɣ] the continuants have the widest distribution. I therefore assume that, at the postlexical level, they are unmarked relative to the stops; as we shall see in section x.x.x, this is the exact opposite of the stem-level régime. Following Baković (1994), I shall implement this idea in optimality-theoretic terms by assuming that spirantization is driven by a constraint against voiced stops:

(3.6) **VOICEDSTOPPROHIBITION (= VSP)**

*[-sonorant, -continuant, +voice]

VSP is phonetically grounded. As is well known, vocal fold vibration can only be maintained if air pressure is lower above the glottis than it is below. In the articulation of voiced stops, however, transglottal pressure differences tend to be levelled very rapidly, as air cannot escape from the oral cavity, so that voicing soon ceases unless compensatory manoeuvres are undertaken (such as advancing the root of the tongue or lowering the larynx); see Hayes (1996: §6.2), Ladefoged & Maddieson (1996: 50-52), and references therein.

VSP stands as the more specific constraint in a Pāṇinian relationship with VOP, the well-known constraint against voiced obstruents (Itô & Mester 1998; Kager 1999: 40). In later sections, I shall also have recourse to a constraint against voiced fricatives:

(3.7) **VOICEDFRICATIVEPROHIBITION (= VFP)**

*[-sonorant, +continuant, +voice]

VSP and VFP do not form a harmonic hierarchy, but can be freely reranked with respect to each other. VFP stands in a Pāṇinian relationship with both VOP and the general markedness constraint against fricatives.[8] This constraint system can in all likelihood be simplified by dispensing with VOP, whose function can be discharged by VSP and VFP in combination; below, references to VOP can be understood as implying VSP plus VFP.

Spirantization kicks into action under the following ranking:

(3.8) IDENT[Lar] VSP

IDENT[cont] VFP

VSP creates pressure to avoid voiced stops. With devoicing being blocked by IDENT[Laryngeal] (see (3.44) below), any voiced obstruent must accordingly become [+cont], regardless of continuancy specifications in the input. VFP cannot oppose the process because it is ranked low. I assume that the [0cont] option is independently ruled out by high-ranking constraints against nonspecification.

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[8] I assume that a constraint against fricatives exists because, within the obstruent class, fricatives are marked relative to stops; for the phonetic grounding of this markedness difference, see e.g. Ladefoged & Maddieson (1996: 137). Additionally, see Maddieson (1984: 45-48) and Ladefoged & Maddieson (1996: 176-177) for the markedness of voiced fricatives relative to voiceless ones.

Tableau (3.9) illustrates the application of postlexical spirantization to voiced stops in the output of the word level. By substituting $\mathbb{B}$ for ***b*** in the input, however, the reader can check that the analysis generalizes to a noninterleaved, strictly parallel framework:

(3.9)

Postlexical		IDENT[Lar]	VSP	IDENT[cont]	VFP
b	ɸ	*!		*	
	p	*!			
	b		*!		
	β ☞			*	*

For the purposes of this work, this suffices as background to the discussion of Richness of the Base and the Duke of York gambit in the following sections. Therefore, I shall not undertake to account formally for the blocking of spirantization in the contexts listed in (3.3). One can anticipate that this will involve markedness constraints ranked above VSP. It is fair to say, however, that our current understanding of the fine detail is relatively poor. Here I shall only make a few remarks on existing proposals.

Mascaró (1984: 291; 1986: 165) and Harris (1993: 185) treat spirantization as a rule spreading [+cont] to a target voiced obstruent from a preceding continuant segment. In this approach, spirantization cannot take place when the segment preceding the target bears the feature [-cont]. This analysis faces two major problems: first, how to account for the conditioning rôle of coronality when the trigger is a lateral; secondly, how to account for the absence of spirantization in labials preceded by the continuant [v].

As regards the rôle of place, Padgett (1995) made an influential theoretical proposal suggesting that homorganicity is a precondition for the hardening of fricatives after nasals and, by implication, for the failure of spirantization processes in the same environment. Padgett suggests that [continuant] is a dependent of Place in feature geometry. Accordingly, a nasal subject to place assimilation acquires not only the place features but also the continuancy value of the trigger segment. Since continuant nasals are highly marked (Padgett 1995: 34 and references therein), a segment which shares its place node with a nasal will be under pressure to become noncontinuant. Catalan, however, provides a counterexample to Padgett's theory: as shown in (3.4c), Catalan nasals block spirantization even when the following obstruent is heterorganic.[9] This is not a problem if, as argued by Mascaró and Harris, spirantization simply consists of the spreading of [+cont] to the right. However, if there is no connection between [continuant] and Place, the behaviour of laterals remains unexplained.

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9 Spanish provides another counterexample: spirantization is blocked after word-final nasals even though the latter do not undergo place assimilation, the impression of homorganicity being a product of gestural overlap in phonetic implementation (Navarro Tomás 1977).

As regards the failure of [b] to spirantize after [v], one could plausibly treat this as an antigemination effect, for ungrammatical *[vβ] contains two adjacent labial fricatives. (We may assume that the difference between labiodental [v] and bilabial [β] is one of stridency, rather than place.) There is some independent evidence that homorganic fricative sequences are subject to antigemination effects in Catalan. As Wheeler (1979: 212-213, 321ff.) observes, groups of two identical consonants are usually pronounced as long singletons, but the clusters [ff], [ss], [zz], [ʃʃ] and [ʒʒ] are phonetically realized as short segments: e.g. *gat timid* [gatːimit] 'shy cat', but *buf fort* [bufɔrt] 'strong puff'.[10] However, this approach flounders upon the observation that the sequence [zð] is perfectly grammatical: note the examples [əzðeβeni] and [ez ðu] in (3.4f). Here we have two adjacent coronal fricatives which presumably differ only in terms of stridency, yet spirantization does not fail, nor is there fusion into a singleton.

Perplexing though these idiosyncrasies are, they do not affect the analysis below. I now turn to another quirk of spirantization whose solution is comparatively straightforward, but whose theoretical implications will prove momentous.

3.2. A puzzle: the failure of spirantization in the coda

In the previous section, as I introduced the facts of spirantization, I pointed out that (3.3) would require two qualifications. The first, and by far the most important, is that spirantization never occurs in the coda: whilst the voiced stops [b, d, g] can be found in rhymal position, the continuants [β, ð, ɣ] are confined to the onset (Fabra 1912: §3, §15-III*; Mascaró 1984: 294; Hualde 1992: 369).

(3.10)	*abdica*	[ə**b**.di.kə]	'he abdicates'
	objecte	[u**b**.ʒek.tə]	'object'
	sublunar	[su**b**.lu.nar]	'sublunar'
	llop dolent	[ʎo**b**.du.len]	'bad wolf'
	llop negre	[ʎo**b**.nɛ.ɣrə]	'black wolf'

[10] Hualde (1992: §3.4.3.2) states this generalization somewhat differently. He claims that any sequence of two identical *nonlabial* continuants (including affricates and rhotics) is reduced to a singleton. As regards [ff], however, he asserts that "A sequence of two labiodental fricatives may be reduced to one, but rearticulation or a perceptibly longer duration is also normal in this case: *buf fenomenal* [búfːənumənál] 'wonderful blow'" (Hualde 1992: 401).

In contrast, Recasens (1991: 198) suggests that labiodental fricative sequences undergo simplification in the same way as other fricative groups: "Dues labiodentals successives presenten fusió en una labiodental simple, llevat de l'alguerès, i de la resta de dialectes quan ambdues consonants successives són emeses en pronúncia acurada [...]" [Two consecutive labiodentals show fusion into a single labiodental, except in the dialect of Alghero, and in the other dialects when both consecutive consonants are produced in careful pronunciation — translation mine].

advertir	[ə**d**.bər.ti]~[əb.bər.ti]	‘to warn’
atleta	[ə**d**.lɛ.tə]~[əl.lɛ.tə]	‘athlete’[11]
gat gelós	[ga**d**.ʒə.los]	‘jealous cat’
gat real	[ga**d**.re.al]	‘real cat’
Bagdad	[bə**g**.dat]	‘Baghdad’
examen	[ə**g**.za.mən]	‘examen’
enigma	[ə.ni**g**.mə]	‘enigma’
amic nou	[ə.mi**g**.nɔw]	‘new friend’
amic ros	[ə.mi**g**.ros]	‘blond friend’

This must be seen as a very intriguing state of affairs in the light of two reflections:

(i) If the analysis propounded below (§x.x.x) is right, and the continuants [β, ð, ɣ] arise postlexically through the spirantization of stops derived at the stem level from underlying /𝔹, 𝔻, 𝔾/, then spirantization must be regarded as a case of lenition not only diachronically but also in genuinely synchronic terms. Yet the syllable coda is a prime target for lenition processes and, accordingly, the last place where one would expect spirantization to fail. Harris (1990: 270) notes that intervocalic position is “the lenition context *par excellence*”, and Kenstowicz (1994: 35) points out that spirantization is often restricted to environments where the target is both preceded and followed by a vowel. Adjacency to a following consonant cannot however be the key to the failure of Catalan spirantization in the coda, for the incidence of the process in onsets shows that the target need not be flanked by vowels: e.g. *arbreda* [ər.**β**ɾɛ.ðə] ‘grove’, *gos blanc* [goz.**β**laŋ] ‘white dog’. Indeed, there appears to be no more reason for spirantization to fail in *sublunar* [su**b**.lu.nar] ‘sublunar’ than there is in *el botó* [əl.**β**u.to] ‘the button’.

(ii) As Mascaró (1984) points out, other languages of the Iberian Peninsula such as Spanish and Basque have near-identical spirantization processes, yet neither in Spanish nor in Basque is spirantization blocked in the coda; see also Fabra (1912: §15-III*). Compare, for example, the following Spanish items with their Catalan cognates in (3.10):

(3.11)	*abdica*	[a**β**.ði.ka]	‘he abdicates’
	advertir	[a**ð**.βeɾ.tiɾ]	‘to warn’
	enigma	[e.ni**ɣ**.ma]	‘enigma’

These considerations suggest that in an adequate analysis the failure of voiced coda obstruents to spirantize should follow from independently motivated properties of Catalan phonology. One would thus be able to retain a crosslinguistically natural statement of the environment of spirantization, and to reduce the differences between spirantization in the several Iberian languages to other particular aspects of their phonology.

[11] Of the two alternatives given here, [əd.lɛ.tə] is characterized as ‘particularly learned’ by Recasens (1991: 218) and as ‘hypercorrect’ by Wheeler (1980: 609). Coronal plosives usually undergo total assimilation to a following noncontinuant (Hualde 1992: §3.4.1.1.4), hence [əl.lɛ.tə] and [əb.bər.ti].

3.2.1. Mascaró's solution

Mascaró (1984: §4; 1986: 165-166) deals with the problem by proposing that Catalan phonology includes rule (3.12), to which I shall henceforth refer as 'coda fortition'.

(3.12)
$$[\text{-son, +voi}] \longrightarrow [\text{-cont}] \;/\; \underset{\underline{\quad | \quad}}{\text{R}}$$

Mascaró assumes that nonsibilant voiced obstruents are underlyingly unspecified for continuancy: i.e. /B, D, G/. Operating in structure-building fashion, rule (3.12) assigns [-cont] to these segments when they occur in the coda. In turn, the specification [-cont] blocks spirantization, which is conceived of as a feature-filling spreading rule (see §x.x.x). Thus, coda fortition bleeds spirantization.

So far, Mascaró's rule provides little more than a restatement of the problem. Moreover, it fails to deal with the typological question, for one expects fortition processes not to apply in the coda; rather, strengthening typically affects onset consonants (in particular word- or utterance-initially) and geminates (Kenstowicz 1994: 35-36). Nonetheless, Mascaró claims that (3.12) discharges an independent function in the phonology of Catalan, in that it can be argued to trigger /ʒ/-affrication. In the coda, underlying /ʒ/ surfaces as an affricate whose voicing is determined by the environment: [dʒ] before voiced sounds and [tʃ] elsewhere (see e.g. Wheeler 1979: 309-310).[12]

(3.13) /𝔹ɔʒ/ 'mad'

	boja	[bɔ.ʒə]	'madwoman'
	bogeria	[bu.ʒə.ɾi.ə]	'madness'
but			
	boig	[bɔtʃ]	'madman'
	boig petit	[bɔtʃ.pətit]	'small madman'
	boig gran	[bɔdʒ.ɣɾan]	'big madman'
	boig estrany	[bɔ.dʒəs.tɾaɲ]	'strange madman'

The fact that word-final /ʒ/ becomes an affricate even when resyllabified into the onset before a vowel-initial word suggests that affrication (and, by the same token, coda fortition in Mascaró's analysis) cannot be postlexical: it must apply at either the stem or the word level. Note, moreover, that coda /ʃ/ does not undergo affrication; see (3.14) for some examples. /ʒ/-affrication must therefore precede word-level coda devoicing (more on which below): e.g. *boig* /𝔹oʒ/ —> [bodʒ] —> [botʃ] 'madman'; the opposite order would generate the ungrammatical mapping /𝔹oʒ/ —> *[boʃ]. This counterbleeding interaction will follow as a necessary consequence if we assign /ʒ/-affrication to the stem level. However, the ascription of /ʒ/-affrication to the stem level requires a number of ancillary assumptions concerning the stratal affiliation of affixes, stem-level cyclicity, and (possibly) the distribution of thematic vowels. Although none of these auxiliary postulates seems implausible, I cannot

[12] In practice, the only instances of coda /ʒ/ are found before the plural suffix *-s* and word-finally. See Mascaró (1984: note 13).

follow them up here; I will therefore regard the assignment of /ʒ/-affrication to the stem level —as opposed to the word level— as provisional. Either way, coda fortition will bleed postlexical spirantization, as required. Moreover, tokens of coda [ʒ] derived from [ʃ] by postlexical voicing assimilation will correctly fail to affricate (Wheeler 1979: 309):

(3.14) /mәteʃ/ 'same'

mateix	[mә.teʃ]	'same' masc.
mateixa	[mә.te.ʃә]	'same' fem.
mateix corb	[mә.teʃ.kɔrp]	'same raven'
mateix gos	[mә.teʒ.ɣos], *[-dʒ-]	'same dog'
mateix home	[mә.te.ʒɔ.mә], *[-dʒ-]	'same man'

However, if coda fortition is to trigger /ʒ/-affrication at the same time as it blocks spirantization, it cannot apply in simple feature-filling mode nor in feature-changing fashion. Rather, (3.12) must be designated as strictly structure-building, but it must be endowed with the power to apply to segments already specified for continuancy. In the case of underlyingly unspecified /B, D, G/, the rule simply supplies the missing values for [cont]. In the case of /ʒ/, however, the input already bears the feature [+cont]; this specification must be retained whilst coda fortition inserts [-cont], yielding a single segment with a [-cont][+cont] contour (Mascaró 1984: 296). A crucial implication, however, is that (3.12) can turn any voiced strident fricative into an affricate.

In the case of [v], this prediction creates no problems, at least in the standard dialect. In Standard Catalan the voiced labiodental fricative only arises through the application of postlexical voicing assimilation to underlying /f/.[13] Since we have concluded that coda fortition cannot be postlexical, [v] will therefore be absent from its input. However, the absence of phonemic /v/ in the standard language is the result of a diachronic process still in

[13] "The only occurrences of phonetic [v] in the dialect studied are those derived from /f/ by the voicing assimilation rule [...:] *baf desagradable* [bávðәzәɣrәðábblә] 'unpleasant fumes'" (Wheeler 1979: 200). Nonetheless, Wheeler (1979: 200-202) postulates an abstract phoneme /v/ to deal with abnormal alternations such as the following (see also Hualde 1992: 399-400):

(a) *blau* [blaw] 'blue' masc. ~ *blava* [blaβә] 'blue' fem. underlying /v/?
serf [serf] 'serf' masc. ~ *serva* [serβә] 'serf' fem. underlying /v/?

Compare the behaviour produced by regular phonological processes:

(b) *geliu* [ʒәliw] 'icy' masc. ~ *geliua* [ʒәliwә] 'icy' fem. underlying /w/
llop [ʎop] 'he-wolf' ~ *lloba* [ʎoβә] 'she-wolf' underlying /𝔹/
xop [ʃop] 'soaked' masc. ~ *xopa* [ʃopә] 'soaked' fem. underlying /p/

Since the alternations in (a) are no longer productive in the standard (as shown for example by the behaviour of loans), I assume that they do not involve phonological derivation from a common root, but simple lexical look-up. In other words, the morphological structure of the feminine forms $[_{A}[_{A}$*blav*$]$*a*$]$ and $[_{N}[_{N}$*serv*$]$*a*$]$ does not define phonological domains; it is 'nonanalytic' in the sense of Kaye (1995: §2.2.2).

progress, and so a contrast between /f/, /v/ and /𝔹/ can still be found in various dialects, notably throughout the Balearic Islands and in areas of Valencia (see e.g. Recasens 1991: 194-196). In these dialects, some stipulation would be required to prevent coda fortition from applying to underlying /v/ in the coda, yielding *[b͡v]~*[p͡f]: e.g. /serv/ —> *[serp͡f] instead of [serf] *serf* 'serf' masc.; cf. fem. *serva* [servə], standard Catalan [serβə].[14] One possibility would be to claim that (3.12) is bound by Structure Preservation, so that its output must conform with the same restrictions that apply to the underlying segment inventory; this would block the creation of novel labial affricates. If /ʒ/-affrication is stem-level, as claimed above, then the structure-preserving character of coda fortition would not need to be stipulated; if, however, /ʒ/-affrication turned out to be word-level, then Structure Preservation would not hold automatically (Borowsky 1993).

Nonetheless, the problem becomes more pressing in the case of /z/, which is alive and well in the standard. Why does (3.12) not apply to coda /z/, yielding [d͡z]~[t͡s]?: e.g. /frənsɛz/ —> *[frənsɛt͡s] instead of [frənsɛs] *francès* 'French' masc.; cf. fem. *francesa* [frənsɛzə]. The appeal to Structure Preservation will only work if one can prove that /dʒ/ and /tʃ/ are singletons with intrasegmental continuancy contours (i.e. /d͡ʒ/ and /t͡ʃ/), whilst /dz/ and /ts/ are mere bisegmental clusters; see Wheeler (1979: 202-207) for a survey of the arguments. Another possibility is to limit the application of coda fortition to [+distributed] segments. Standard Catalan /z/ is described as apico-alveolar, and so may be assumed to be [-distributed]; /ʒ/, in contrast, must be [+distributed] since it has a lamino-alveolar constriction accompanied by raising of the front of the tongue (see e.g. Wheeler 1979: xxi; Recasens 1991: 172). The proposal seems workable, as one can make a case for also specifying /B/, /D/ and /G/ as [+distributed].[15] In fact, Mascaró (1984: 296) implicitly endorses this course of

[14] The hypothesis has been advanced that phonemic /v/ is only preserved in those dialects in which /𝔹/ fails to undergo spirantization to [β]; the phonetic similarity between [v] and [β] is argued to be too great to allow the maintenance of a phonological contrast (see Recasens 1991: 183 and references therein). If that were indeed the case, then dialects with /v/ would either lack the spirantization rule or restrict its application to nonlabial segments. By the same token, these dialects would not require the coda fortition rule, at least for labials, and so the possibility of (3.12) creating *[b͡v]~*[p͡f] out of underlying /v/ would not even arise. However, Recasens (1985) reports that a distinction between [v] and [β] as allophones of /v/ and /𝔹/, respectively, survives in certain dialects spoken in the Camp de Tarragona. This phenomenon does not lack crosslinguistic parallels. As noted by Ladefoged & Maddieson (1996: 139), several West African languages have a phonemic opposition between /β/ and /v/: e.g. Ewe /èβè/ 'the Ewe language' vs /èvè/ 'two'. Even more relevantly, Ladefoged & Maddieson observe that in some Bantu languages possessing a /β/~/v/ contrast, such as Tsonga, /β/ arose historically through the spirantization of bilabial stops (see further Maddieson 1984: 46). In this sense, the state of affairs reported by Recasens (1985) as obtaining in the Camp de Tarragona is not unique, but largely analogous with that of Tsonga.

[15] The case, however, is not water-tight. As regards /B/ and /G/, these segments cannot be specified for [distributed] if this feature is a dependant of the coronal node in feature geometry (Kenstowicz 1994: 30-31, 452). The status of /D/ is even more uncertain. Mascaró's (1983: 80-81) characterization of the surface phone [d̪] as [+distributed] appears uncontroversial; Recasens' (1991: 172) phoneme chart labels his /d/ as apico-dental rather than lamino-dental, but, as Ladefoged & Maddieson (1996: 23) point out, "There are comparatively few languages in which a dental stop is required to be apical." Nonetheless, Kiparsky (1985: §1.5) claims that underlying /𝔻/ and /t/ have alveolar rather than dental reflexes at the stem and word levels; he suggests that dentalization only takes place postlexically (by which time coda fortition would already have applied). Kiparsky's

action by glossing the application of coda fortition in a diagram with the following prose statement: “Assign [-cont] to [-son, +voice, -distr] in syllable rime” (*sic*).[16] I would suggest, however, that the connection between /ʒ/-affrication and the failure of spirantization in codas is fundamentally weakened if the target of coda fortition has to be stipulatively specified as [+distributed]; this feature is totally irrelevant to the operation of spirantization.

In fact, there is reason to believe that in the majority of Catalan dialects the behaviour of /𝔹, 𝔻, 𝔾/ in codas is independent from /ʒ/-affrication.[17] The latter is better understood in the light of the fact that contrasts between fricatives and affricates with the same voicing and place of articulation are crosslinguistically somewhat infrequent and prone to neutralization, particularly in nonintervocalic environments. Consider the situation in Catalan itself (Wheeler 1979: 203-204; Hualde 1992: 370-372, 379-381):

(i) The sounds [ts] and [dz] do not occur word-initially other than in unassimilated loans: e.g. *tse-tse* (Hualde 1992: 379). Similarly, they are not permitted stem-finally. In word-final position, they arise only through the addition of the plural morpheme *-s* to a base ending in a coronal stop: e.g. *gat+s* [gats] ‘cats’, *gat+s bonics* [gadz βuniks] ‘pretty cats’ (Hualde 1992: 380-381). Morpheme-internally in intervocalic position, however, /dz/ contrasts freely with /z/: e.g. *atzar* [ədzar] ‘fate’ vs *asil* [əzil] ‘asylum’.[18]

(ii) In the standard dialect, [tʃ] occurs word-initially only in a few loans such as *txec* [tʃɛk] ‘Czech’; [dʒ] is entirely absent in this environment (Hualde 1992: 370). The opposition between palatoalveolar fricatives and affricates is also neutralized postconsonantally, where Standard Catalan only allows the fricatives (Wheeler 1979: 203-204). In other dialects, neutralization occurs in exactly the same contexts, but is resolved in the opposite way, with

claim relies on the simplification process whereby word-final homorganic nasal+plosive clusters lose their second member: when the final stop is deleted in items such as *vint* ‘twenty’, the preceding nasal emerges as alveolar rather than dental, i.e. [bin] rather than *[bin̪] (see Hualde 1992: 402). However, late dentalization of /𝔻/ and /t/ is not the only possible scenario: Recasens (1991: 221) suggests that stop deletion produces [bin̪], but the coronal nasal has its place features adjusted in line with /n/. If Recasens is right, then underlying /D/ could be [+distributed] after all.

[16] I assume that “-distr” is a typographical error for “+distr”.

[17] Evidence of an intimate connection between spirantization and /ʒ/-affrication exists only in the dialect of the Empordà (Hualde 1992: 371). Here, as in the standard, the phonemes /dʒ/ and /ʒ/ contrast intervocalically; in this respect, their behaviour differs from that of [d] and [ð], whose occurrence is predictable everywhere. In the Empordà, however, the distribution of [dʒ] and [ʒ] in all other environments mirrors that of [d] and [ð]. Word-initially, and word-medially after a consonant, [dʒ] is found in the same contexts as [d]: i.e. after pause, a stop, a nasal or a lateral; [ʒ], in turn, occurs in the same contexts as [ð]: i.e. after a vocoid or a continuant. Word-finally, only [dʒ] and [d] are allowed, as in the standard. Suggestive though these distributional parallels are, they do not hold for the majority of Catalan dialects: the standard has [ʒ] to the exclusion of [dʒ] word-initially as well as word-medially after a consonant, regardless of the character of the preceding segment; other dialects have [dʒ] to the exclusion of [ʒ].

[18] Hualde (1992: 370) writes, “I am aware of only one example of morpheme-internal [ts], *lletsó* [ʎətsó] ‘sow-thistle’.” On the sparseness of [ts] as opposed to the ordinary distribution of [dz], Wheeler (1979: 205) offers the following comment: “The rarity of [ts] except where it is from /t+s/ or /d+s/ is just a curious fact of Catalan.”

[ʃ] and [ʒ] banned word-initially and after consonants; see Recasens (1991: 283-287, 292, 296-297) for details.

In this light, it is relatively unsurprising that /ʒ/ should undergo affrication in the coda; we can now see that the contrast between /ʒ/ and /dʒ/ is in fact only maintained word-medially between vowels. Voiceless /ʃ/ and /tʃ/ behave slightly differently, in that their opposition survives word-finally; but this is not altogether unexpected, for the voiceless palatoalveolars are unmarked relative to their voiced counterparts.[19] A strikingly similar state of affairs holds in present-day English. The language displays a robust phonemic distinction between /ʃ/ and /tʃ/ not only intervocalically, but also in word-initial and word-final positions. The voiced fricative /ʒ/, in contrast, only holds its ground against the affricate /dʒ/ between vowels; word-initial and word-final [ʒ] are only found in French loans, where replacement by [dʒ] is common (Gimson 1989: 189).

In conclusion, Mascaró's rule of coda fortition fails to solve the problem of the absence of spirantization in the rhyme. His proposal does not attempt to reconcile the facts of Catalan with the typological generalization that codas favour lenition rather than strengthening. Moreover, the rule has scant independent motivation: its extension to /ʒ/-affrication requires complex additional stipulations and proves in any case superfluous, given the abundant independent evidence that fricative-affricate distinctions tend to be neutralized in all environments other than intervocalically.

Interestingly, Mascaró's approach has lately been revived in the framework of OT. McCarthy (1998: §5) cursorily suggests that the failure of spirantization in the coda can be attributed to a universal violable constraint prohibiting coda fricatives; this constraint, which I shall label NoCodaFric, is alleged to be documented in Korean, Kiowa (Zec 1995: 111-112) and Nancowry (Alderete *et al.* 1997). However, McCarthy's proposal incurs empirical difficulties similar to those encountered by rule (3.12). Notably, Catalan does tolerate fricative segments in the rhyme: namely, [f, v, s, z, ʃ]. Since these coda fricatives are all strident, one could narrow the target of NoCodaFric appropriately by conjoining it locally with a constraint requiring that continuant obstruents should be strident; I formulate such a constraint under the label Fric—>Strid in (3.37) below. Nonetheless, spirantization could still circumvent the macroconstraint NoCodaFric&Fric—>Strid by mapping /𝔹/ onto [v] and /𝔻/ onto [z] in the coda. To salvage McCarthy's suggestion, therefore, faithfulness constraints would have to be brought in to block such mappings. Here, however, an insurmountable obstacle appears, as I shall demonstrate in section x.x.x. In those Catalan dialects, such as the standard, which lack a voiced labiodental fricative phoneme, the strident phone [v] is in complementary distribution with its nonstrident counterpart [β]; as a result, the stridency specifications of labial continuants are fully predictable. Richness of the Base therefore demands that /𝔹/ should be rich in stridency specifications: more specifically, *v* is a possible instantiation of /𝔹/. By the same token, the mapping /𝔹/—>[v] cannot be blocked by faithfulness constraints. Thus, McCarthy's suggestion, though appealing at first blush, proves unworkable. For more

[19] In the UPSID database (Maddieson 1984), there are 146 languages described as having /ʃ/ and 141 as having /tʃ/, whilst 80 are listed as having /dʒ/ and only 51 as having /ʒ/. Additionally, only 2 of the 51 languages with /ʒ/ lack /ʃ/ (Maddieson 1984: 47).

extensive discussion, the reader is referred to section x.x.x, where I explore sympathy-theoretic treatments of Catalan voicing and continuancy in more detail.

3.2.2. Harris's solution

The real reason for the failure of Catalan voiced stops to undergo spirantization in the coda was discovered by James Harris in his contribution to the Bromberger festschrift (Harris 1993). The following account is closely based upon his analysis, but there will be some significant differences in execution. These will follow from my rejection of extrinsically ordered phonological rules in favour of constraints, with the corollary that opacity is impossible within cycles, but can only arise through the interaction between strata.

Let us start by considering a subset of coda obstruents: those occurring word-finally before a consonant-initial word. In this environment, the stops [b, d, g] are often derived from underlying /p, t, k/ through assimilation to a following voiced consonant:

(3.15) /𝔾at/ ‘cat’

gat	[gat]	‘cat’ masc.
gata	[ga.tə]	‘cat’ fem.
gat anglés	[ga.təŋ.glɛs]	‘English cat’
gat feliç	[gat.fə.lis]	‘happy cat’
gat gelós	[gad.ʒə.los]	‘jealous cat’

In this example we know that the final consonant of the stem is underlyingly voiceless because it is realized as [t] in the onset before the feminine suffix *-a*. In *gat gelós*, however, voicing assimilation to the following fricative has turned underlying /t/ into a voiced obstruent. Since the voicing assimilation process applies across word boundaries, one must conclude that it is postlexical, like spirantization. Nonetheless, its output fails to spirantize. Harris handles this fact by means of extrinsic ordering within the postlexical module: voicing assimilation is claimed to follow —and therefore counterfeed— spirantization.

(3.16)	*gat feliç*	*gat gelós*
Underlying representation	/𝔾at fəlis/	/𝔾at ʒəlos/
Postlexical level		
Input	.gat.fə.lis.	.gat.ʒə.los.
Spirantization	—	—
Voicing assimilation	—	.gad.ʒə.los.
	‘happy cat’	‘jealous cat’

In section x.x.x I shall show that the interaction between spirantization and voicing assimilation within the postlexical stratum is in fact transparent: it can be modelled in interleaved OT without recourse to extrinsic ordering. At this point, however, we need just remember that stops voiced by postlexical assimilation remain noncontinuant; spirantization fails to apply to segments which are voiceless in the input to the postlexical module.

As the next step in the argument, notice that in word-final position underlying /𝔹, 𝔻, 𝔾/ behave in exactly the same way as /p, t, k/: cf. (3.15) and (3.17). More generally, obstruent voice contrasts are completely neutralized word-finally.

(3.17) /ʎo𝔹/ ‘wolf’

llop	[ʎop]	‘he-wolf’
lloba	[ʎo.βə]	‘she-wolf’
llop amic	[ʎo.pə.mik]	‘friendly wolf’
llop trist	[ʎop.trist]	‘sad wolf’
llop lliure	[ʎob.ʎiw.ɾə]	‘free wolf’

In this case we can ascertain that the stem-final consonant is underlyingly voiced by inspecting its realization in the feminine form *lloba*, where it occurs word-medially in onset position. In the masculine citation form *llop*, however, underlying /𝔹/ has undergone devoicing to [p]. Word-final codas must accordingly be subject to a process of obstruent devoicing. However, this process cannot be postlexical but must kick into action at the word level, because it overapplies to word-final obstruents subject to resyllabification into the onset before vowel-initial words: see *llop amic*.[20] Consider now *llop lliure*, where underlying /𝔹/ surfaces as unspirantized [b]. Now that it has been established that word-final /𝔹/ undergoes devoicing at the word level, the failure of surface [b] to spirantize stands explained: the voiced stop is the result of the postlexical assimilation of word-level [p] to the following voiced consonant —and, as we established above, stops subject to voicing by postlexical assimilation do not spirantize.

[20] As we shall see in the following subsection, Harris (1993) assigns devoicing to the postlexical module in order to deal with the absence of devoicing before the accusative 3sg.neut. enclitic *-ho* [-u]. As a consequence, he is forced to order devoicing before postlexical resyllabification, so that attraction into the onset of a vowel-initial nonenclitic word may still counterbleed devoicing. I shall argue, however, that Catalan enclitics are word-level affixes, rendering this piece of extrinsic ordering superfluous.

(3.18)	*llop*	*lloba*	*llop amic*	*llop lliure*
UR	/ʎo𝔹/	/ʎo𝔹ə/	/ʎo𝔹 əmik/	/ʎo𝔹 ʎiwɾə/
WL				
Input[21]	.ʎob.	.ʎo.ba.	.ʎob. .ə.mik.	.ʎob. .ʎiw.ɾə.
Devoicing	.ʎop.	—	.ʎop. .ə.mik.	.ʎop. .ʎiw.ɾə.
PL				
Resyllabification	—	—	.ʎo.pə.mik.	—
Spirantization	—	.ʎo.βə.	—	—
Voicing assimilation	—	—	—	.ʎob.ʎiw.ɾə.
	'he-wolf'	'she-wolf'	'friendly wolf'	'free wolf'

Now, at last, we are in a position to tackle the behaviour of nonstrident voiced obstruents in word-medial codas. The first point to note is that in this environment laryngeal distinctions among nonsonorants are completely neutralized, just as they are in word-final position: a word-internal rhymal obstruent must obligatorily agree in voicing with the following consonant. This fact is straightforwardly derived if the postlexical process of assimilation postulated above applies to all codas across the board. However, the similarity between word-internal and word-final rhymes goes even further. As we saw in (3.10), nonstrident voiced obstruents fail to spirantize in the coda not only word-finally but also word-internally. Harris's (1993) brilliant insight was to realize that their derivation must therefore be identical in both contexts. Recall: a voiced stop resists spirantization when it is voiceless in the input to the postlexical module. It follows that, since word-internal [b, d, g] escape spirantization in the rhyme, in that environment they must derive from word-level [p, t, k]. By implication, word-level devoicing must apply to all coda obstruents, whether word-medial or word-final.

This analysis involves a significant departure from traditional descriptions of voicing neutralization in Catalan. Voicing assimilation and devoicing are usually described as two complementary components of a single neutralization process. Devoicing, in particular, is conceived of as a default rule targeting those rhymal obstruents which are unable to assimilate: e.g. those in absolute final position, where no following onset consonant is available to trigger assimilation (see Mascaró 1987: specially §1). In this sense, the interaction between devoicing and assimilation is assumed to be transparent. Harris's arguments demonstrate that this approach oversimplifies the facts. The domains of devoicing and assimilation are not complementary but overlap to a very high extent; where conflict occurs, postlexical assimilation effaces the application of word-level devoicing. Their interplay results in opacity.[22] As Harris (1993: 190) points out:

[21] Recall that underlying /𝔹, 𝔻, 𝔾/ are mapped onto voiced stops at the stem level; see section x.x.x.

[22] In section x.x.x, however, I will show that Harris's proposals must be revised in such a way as to bring them closer in line with traditional approaches. In the modified version of Harris's analysis, word-level voice neutralization does not involve devoicing, but simply delinks the laryngeal features of coda obstruents (delaryngealization). The missing laryngeal specifications are then supplied postlexically by assimilation, with voicelessness being assigned by default in nonassimilation environments. Crucially, if postlexical spirantization

> [...] This rule [sc. devoicing] is commonly but mistakenly seen as word-final rather than syllable-final devoicing.
> [...] Mascaró (1984) stipulates that Spirantization does not apply to coda segments. This restriction can be eliminated if rule (15a) [sc. devoicing] is generalized from a word-final to a syllable-final operation [...].

I shall now look in some detail at a concrete instance of the failure of spirantization in word-medial codas; but, first, we must ascertain the rôle of Richness of the Base. Consider an underlying obstruent /**α**/. If no token of /**α**/ occurs in the onset at the word level, then the laryngeal specifications of /**α**/ will be irrelevant to its ultimate fate: it will undergo word-level coda devoicing, and will surface as voiceless except when subject to voicing by postlexical assimilation. Accordingly, Richness of the Base compels us to regard any nonsonorant segment as underlyingly rich in laryngeal features if the segment never surfaces in onset position other than by postlexical resyllabification. In the word *enigma* [ə.nig.mə] 'enigma', for example, the obstruent always surfaces in the rhyme; its underlying representation will therefore be indeterminate between voiced /𝔾/ and voiceless /k/. Its derivation is laid out in (3.19). Underlying /𝔾/ undergoes coda devoicing to [k] at the word level, whilst underlying /k/ satisfies word-level phonotactics vacuously. Postlexically, [k] assimilates in voicing to the following nasal; but, as we have repeatedly asserted, voice assimilation fails to feed spirantization.

(3.19)		*enigma*	
Underlying representation	/əni𝔾mə/	or	/ənikmə/
Word level			
Input	.ə.nig.mə.		.ə.nik.mə.
Devoicing	.ə.nik.mə.		—
Postlexical level			
Spirantization	—		—
Voicing assimilation	.ə.nig.mə.		.ə.nig.mə.
		'enigma'	

In sum, the failure of spirantization in the rhyme is due to its interaction with two opposite but largely overlapping processes of voice neutralization: word-level devoicing and postlexical assimilation. Nonstrident voiced obstruents undergo spirantization if, and only if, they are already voiced in the input to the postlexical module. Spirantization is impossible in the coda simply because all rhymal obstruents are voiceless in the output of the word level: word-level devoicing applies to all codas and not simply as the default in the absence of an assimilation trigger, *pace* Mascaró (1987). Postlexical assimilation creates new tokens of [b, d, g] in the rhyme, but these fail to undergo spirantization.

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only applies to stops which are voiced in the input to the postlexical module, then word-level delaryngealization would have a bleeding effect identical to that of devoicing. As section x.x.x will show, the choice between word-level devoicing and word-level delaryngealization rests on subtle considerations in the analysis of prefix-final and word-final fricatives, which behave unexpectedly by undergoing voicing in prevocalic (onset) position.

Observe that this analysis fulfils the two desiderata stated at the outset of this subsection. First, one is able to retain a crosslinguistically natural statement of the environment of spirantization: like other prototypical lenition processes, spirantization does target the coda; its failure in this environment is a mere epiphenomenon of the absence of proper inputs, which are removed by word-level devoicing. Secondly, spirantization can be seen to operate in much the same way in Catalan as it does in other Iberian languages: the process gets a chance to apply to codas in Spanish and Basque simply because these languages do not have rules of devoicing applying at the word level.

Behind Harris's analysis there lies a brilliant piece of abduction. One has access to two premises: first, the generalization (established on the evidence of word-final consonants) that voiceless obstruents subject to voicing by postlexical assimilation resist spirantization; secondly, the observation that, in effect, word-internal voiced codas fail to spirantize. From this one can infer the cause: namely, that word-internal voiced codas are voiceless in the output of the word level and undergo assimilatory voicing postlexically. In the following sections, however, I will show that one can improve upon Harris's original analysis by recasting it in terms of interleaved OT. My reformulation will remove all traces of stratum-internal opacity, thereby dispensing with extrinsic rule ordering altogether. Moreover, we shall see that interleaved OT reinstates the domain of application of a phonological process as the main criterion guiding ascription to a particular level in the grammar: e.g. coda devoicing must be word-level because it overapplies to word-final consonants resyllabified into the onset; spirantization and voice assimilation must be postlexical because they both apply across the board, blind to morpheme or word boundaries. The use of extrinsically ordered rules within levels can obfuscate the evidence of grammatical domains: e.g. Harris is able to assign devoicing to the postlexical level by stipulatively ordering it before resyllabification (see footnote 20 and below). Interleaved OT allows no such ploys.

3.3. Word-level devoicing and syllabification

We have established that Catalan voiced obstruents, including nonsibilant /$\mathbb{B}$, $\mathbb{D}$, $\mathbb{G}$/, undergo devoicing in the coda at the word level. From a typological viewpoint coda devoicing is an unremarkable process, and the constraint hierarchy which triggers it is relatively well understood (see §x.x.x). To account for the specific facts of Catalan, however, one must also answer the following two questions. First, we must find out what syllabification régime holds at the word level, as this will determine whether or not an obstruent will occupy the coda and undergo devoicing. Secondly, one must address the effect of devoicing upon the [continuant] values of nonsibilant voiced obstruents: in particular, if underlying /$\mathbb{B}$, $\mathbb{D}$, $\mathbb{G}$/ are rich in continuancy specifications, why is it that under devoicing they are realized as the stops [p, t, k], rather than as continuant segments such as *[ɸ, θ, x]?

3.3.1. Prefixes

Word-level syllabification is crucial as a test of our claim that devoicing targets all rhymal obstruents, rather than just those unable to assimilate. In this respect, Harris (1993: §3) draws our attention to the significant behaviour of nonsonorant consonants in two environments: prefix-finally, and verb-finally before enclitic pronouns. I shall first consider prefix-final obstruents: (3.20) provides examples of words derived by means of the productive prefix *sub-* ‘sub-’.

(3.20)	(a)	*subtip*	[su**p**.tip]	‘subtype’
		subclasse	[su**p**.kla.sə]	‘subclass’
	(b)	*subdividir*	[su**b**.di.βi.ði]	‘to subdivide’
		subjugar	[su**b**.ʒu.ɣa]	‘to subdue’
	(c)	*sublunar*	[su**b**.lu.nar]	‘sublunar’
		sublingual	[su**b**.liŋ.gwal]	‘sublingual’
	(d)	*subalpí*	[su.**p**əl.pi]	‘subalpine’
		subeditor	[su.**p**ə.ði.to]	‘subeditor’
		subíndex	[su.**p**in.dəks]	‘subindex’

In (3.20d) the final consonant of the prefix surfaces as a voiceless stop in onset position. Its voicelessness could be explained in either of two ways. We could simply assume that the final consonant is /p/ in the underlying representation; being in the onset, its surface laryngeal properties would simply mirror its underlying specification for [voice]. However, this hypothesis is unlikely, for *sub-* ends in an underlyingly voiced segment both in Latin and in the Iberian cognates of Catalan: cf. Spanish *subeditor* [su.**β**e.ði.t̪oɾ] ‘subeditor’. Alternatively, one can suggest that voice contrasts are completely neutralized in prefix-final position, just as they are word-finally. This would imply that prefix-final consonants are never syllabified as onsets at the word level, and are therefore susceptible to coda devoicing. Such an analysis makes two predictions:

(i) Before vowel-initial stems prefix-final obstruents will behave in the same way as word-final nonsonorants subject to postlexical resyllabification. Unfortunately, Catalan appears to have relatively few productive prefixes ending in obstruents, particularly stops (see e.g. Fabra 1912: §193; Hualde 1992: §2.2.5), but those that exist confirm our prediction: e.g. *bes-avi* [bə.za.βi] ‘great-grandfather’, *des-agradar* [də.zə.ɣɾə.ða] ‘to displease’, *sots-arrendar* [so**d**.zə.rən.da] ‘to sublet’.[23]

(ii) Voiced reflexes of prefix-final /𝔹, 𝔻, 𝔾/ can only arise through postlexical assimilation, and must therefore be noncontinuant. This is corroborated by the examples in (3.20b) and (3.20c).

I conclude that, at the word level, Catalan consonants fail to be attracted into an empty onset across a prefix-stem boundary; resyllabification in that environment is confined to the postlexical level. This state of affairs is not out of the ordinary in Romance. A large set of Spanish dialects, for example, have a word-level process of debuccalization whereby underlying /s/ becomes [h] in the coda. Debuccalization cannot be postlexical because it overapplies to word-final fricatives subject to resyllabification into a following onset: e.g. *gas* [gah] ‘gas’, *gases* [ga.seh] ‘gases’, *gas azul* [ga.ha.θul] ‘blue gas’. Significantly, a subset of these dialects disallow [s] in prefix-final position even before vowel-initial stems: e.g. *des-orden* [de.**h**oɾ.ðeŋ] ‘disorder’ (see e.g. Hualde 1989: §4). Hualde (1991: §2.2), Harris (1993:

[23] In anticipation of section x.x.x, note that, unlike stops, word-final fricatives and affricates undergo postlexical assimilatory voicing in prevocalic position.

§2) and Kaisse (1999) interpret this fact as implying that resyllabification across the left edge of stems is absent at the word level but becomes active postlexically.[24]

Resyllabification across the prefix-stem boundary is blocked by a constraint of the ANCHOR format (McCarthy & Prince 1995):

(3.21) **ANCHOR-L**

Let α be a segment in the input.
Let β be a correspondent of α in the output.
If α is initial in a prosodic word, then β is initial in a prosodic word.[25]

ANCHOR-L dominates ONSET at the word level, but is demoted postlexically. I shall also assume that ANCHOR-L outranks NONREC-PWd in the word-level hierarchy:

(3.22) **NONREC-PWd**
No prosodic word dominates a prosodic word.

NONREC-PWd is member of the NONRECURSIVITY family (Selkirk 1996: 190). Under the ranking ANCHOR-L » NONREC-PWd, the word-level prosodification of a form such as *subalpí* will proceed as follows:

(3.23) *Stem level* $[_{\text{PWd}}$.əl.pi.]

Word level
Prefixation sub$[_{\text{PWd}}$.əl.pi.]
Prosodification $[_{\text{PWd}}$.sub.$[_{\text{PWd}}$.əl.pi.]]
Devoicing $[_{\text{PWd}}$.sup.$[_{\text{PWd}}$.əl.pi.]]

In my analysis, ANCHOR-L performs the same function as ALIGN(stem, L; PWd, L) in McCarthy & Prince (1993b). Note, however, that ANCHOR-L does not mention the stem as a morphological category; stem-initial consonants are instead identified indirectly as being PWd-initial in the output of the stem level. This approach follows in the generative tradition of limiting access to morphological information in the phonology. Under interleaving, it is

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24 The overapplication of debuccalization to prefix-final fricatives before vowel-initial stems in certain Spanish dialects has figured prominently in recent debates of output-output correspondence: see Kenstowicz (1996: §4.1); Benua (1997: §6.2); Colina (1997); Hale, Kissock & Reiss (1998); Face (1998); Baković (1998: 22). A number of authors, such as Benua (1997) and Hale, Kissock & Reiss (1998), suggest that the underlying representation of the prefix *des-* in these Spanish dialects is in fact /deh-/ rather than /des-/, so that there is no misapplication. Under this approach, however, the absence of oral fricatives prefix-finally is a mere lexical accident, rather than a phonological generalization. Additionally, this suggestion has momentous implications for the analysis of variable idiolects where [de.hor.ðeŋ] alternates with [de.sor.ðeŋ]; such variation would have to be dealt with in the lexicon rather than the grammar, even in the absence of independent evidence that debuccalization is lexically selective (see Face 1998: 9-10).

25 Note that the term 'prosodic word' designates a suprasegmental constituent, i.e. a member of the prosodic hierarchy . Its meaning must not be confused with that of 'P-word', which refers to a phonological domain: more specifically, any portion of linguistic material within the scope of the word-level phonology. See Inkelas (1993) for discussion.

assumed that phonological generalizations need not refer to specific morphological categories; rather, constraints simply access the visible domain, which bears no morphological specifications. Level segregation and cyclicity independently ensure that only morphological categories of the correct type provide domains for the relevant phonological generalizations (see e.g. Anderson 1992: 245, 249, 289).

In Catalan any stem-internal sequence of a nonstrident obstruent or [f] followed by [l] or [ɾ] forms a complex onset (Wheeler 1979: 242-3; Recasens 1991: 175; Hualde 1992: §3.2.2.2.1): e.g. *sublim* [su.βlim] 'sublime'. However, since CONTACT cannot enforce the word-level resyllabification of prefix-final obstruents before stem-initial vowels, one can infer that there will also be no resyllabification before stem-initial liquids, where the sonority rise is less sharp. This prediction is confirmed by the examples in (3.20c), in which the failure of prefix-final [b] to spirantize indicates that it has undergone coda devoicing at the word level. Interestingly, obstruent+liquid clusters differ from obstruent+vowel sequences in that the former continue to resist resyllabification postlexically:

(3.24)	**Word level**	**Postlexical level**[26]	
subalpí	[$_{PWd}$.sup.[$_{PWd}$.əl.pi.]]	—> [su.pəl.pi]	cf. *[sup.əl.pi] 'subalpine'
sublunar	[$_{PWd}$.sup.[$_{PWd}$.lu.nar.]]	—> [sub.lu.nar]	cf. *[su.plu.nar] 'sublunar'

In this sense, postlexical resyllabification removes onsetless syllables, but stops short of creating maximal onsets: i.e. it is onset-satisfying, but not onset-maximizing. Hualde (1989; 1991: 486) reaches the same conclusion for Spanish. This suggests that, postlexically, ANCHOR-L is demoted with respect to ONSET, but remains ranked above CONTACT.

(3.25) *Word level*: ANCHOR-L » ONSET, CONTACT

Postlexical level: ONSET » ANCHOR-L » CONTACT

In sum, voice contrasts are completely neutralized at the right edge of productive (i.e. word-level) prefixes because prefix-final consonants are always rhymal at the word level; they only surface in onset position when subject to postlexical onset-satisfying resyllabification. Incidentally, this implies that prefix-final obstruents are underlyingly rich in laryngeal specifications: the underlying representation of *sub-* will be indeterminate between /su𝔹/ and /sup/.[27] Compare (3.19) and (3.26):

[26] Postlexical *PWd*-structure is irrelevant to the argument at hand and is omitted here.

[27] I am grateful to Joan Mascaró for discussion of this point.

(3.26)		*sublunar*	
Underlying representation	/su𝔹-lunar/	or	/sup-lunar/
Word level			
Prefixation	sub[$_{\mathrm{PWd}}$.lu.nar.]		sup[$_{\mathrm{PWd}}$.lu.nar.]
Prosodification	[$_{\mathrm{PWd}}$.sub.[$_{\mathrm{PWd}}$.lu.nar.]]		[$_{\mathrm{PWd}}$.sup.[$_{\mathrm{PWd}}$.lu.nar.]]
Devoicing	[$_{\mathrm{PWd}}$.sup.[$_{\mathrm{PWd}}$.lu.nar.]]		—
Postlexical level			
Spirantization	—		—
Voicing assimilation	.sub.lu.nar		.sub.lu.nar
		‘sublunar’	

3.3.2. Enclitics

Let us now consider verb-final obstruents before enclitic pronouns. Harris (1993: 186) supplies the following examples of the verb ‘receive’ (see also Fabra 1912: 122):

(3.27)	(a)	*rebre*	[rɛ.**β**ɾə]	‘to receive’
	(b)	*rep*	[rɛ**p**]	‘receive!’
	(c)	*rep això*	[rɛ.**p**ə.ʃɔ]	‘receive that!’
	(d)	*rep-ho*	[rɛ.**β**u]	‘receive it!’
	(e)	*rep-la*	[rɛ**b**.lə]	‘receive her!’

The infinitive form in (3.27a) shows the root-final consonant to be underlyingly voiced, as its surface realization is voiced in word-medial onset position, where laryngeal contrasts do not undergo neutralization; postlexical spirantization applies because the consonant is voiced in the output of the word level. In (3.27b), underlying /𝔹/ occurs word-finally and, as expected, is subject to word-level coda devoicing; postlexical resyllabification counterbleeds word-level devoicing, as shown in (3.27c). Consider now (3.27d), where the imperative form, consisting of the bare root, is accompanied by an accusative 3sg.neut. enclitic pronoun. Here, the realization of the root-final consonant is identical with that of the infinitive: the voiced continuant [β]. Since postlexical spirantization has applied, the obstruent must be voiced in the output of the word level and therefore syllabified in onset position. This leads one to two conclusions: first, Catalan enclitics (see Hualde 1992: 242-243) behave phonologically like word-level affixes; secondly, Catalan permits onset-satisfying resyllabification across the right-edge of the stem.

Classical Lexical Phonology encounters severe problems over the finding that, from a phonological viewpoint, Catalan enclitics are word-level affixes. In this framework, the word level is assumed to be located in the lexicon. Therefore, since the distribution of clitics depends on syntactic factors, the phonology of host-clitic combinations is expected to be computed at the phrase level, i.e. postlexically. As Berendsen (1986: 144) puts it, if “clitics meet other morphemes in the syntactic component of grammar”, then “phonology applied to clitics and hosts can only be post-lexical”. Berendsen acknowledges that host-clitic combinations may undergo phonological processes whose application is otherwise limited to word domains. He nonetheless argues that such processes are not word-level, but rather postlexical processes bound by the prosodic word. Crucially, *PWd*-bound postlexical processes can mimic the effects of word-level regularities in a rule-based framework, where they can be ordered before other postlexical processes. In interleaved OT, in contrast, word-level processes and *PWd*-bound postlexical processes must have different effects: since there is no opacity within the postlexical module, only word-level processes can interact opaquely with the phrase-level phonology.

In the case of Catalan, it is clear that the distribution of clitics is affected by syntactic factors: clitics precede or follow the verb depending on the finiteness, mood and polarity of the latter; additionally, there are syntactic phenomena of clitic climbing, clitic doubling, and complex constraints on clitic combinations (see Hualde 1992: *passim*). Harris (1993: 189) is clearly impressed with this fact: "Host-clitic combinations," he states, "are 'word sequences' in that clitics have the syntactic distribution of independent words." By his own assumptions, therefore, devoicing must be postlexical, since it is bled by resyllabification across the host-enclitic boundary, even though devoicing itself then bleeds postlexical spirantization. To deal with this problem, he posits two postlexical levels: 'S1' and 'S2'; see Kaisse (1985, 1987) and Mohanan (1986) for similar splits of the postlexical module. Harris suggests that the accusative enclitic *-ho* is introduced in S1, where it triggers resyllabification of the verb-final consonant and so bleeds devoicing, which applies at S2. Within S2, however, Harris is still forced to order devoicing not only before spirantization but also before resyllabification: recall that the resyllabification of a word-final obstruent into the onset of a vowel-initial nonenclitic word counterbleeds devoicing.

(3.28) **Harris's (1993: §3) analysis of Catalan enclitics**

	rep-ho	*rep això*
UR[28]	/rɛb-u/	/rɛb əʃɔ/
Word level	.rɛb.	.rɛb.
S1		
Cliticization	.rɛb.u	—
Resyllabification	.rɛ.bu.	—
S2		
Nonclitic phrasing	—	.rɛb.ə.ʃɔ.
Devoicing	—	.rɛp.ə.ʃɔ.
Resyllabification	—	.rɛ.pə.ʃɔ.
Spirantization	.rɛ.βu.	—
	'receive it!'	'receive that!'

[28] Note that Harris assumes /b/ in the underlying representation, as his rule-based framework countenances constraints on inputs and is therefore not bound by Richness of the Base.

Clearly, the proliferation of postlexical levels in this analysis and its overreliance on extrinsic ordering betray a fundamental problem in the overall grammatical framework. In fact, one can espouse interleaving without assuming that the word-level phonology is computed in the lexicon. Let us define the word-level phonology as the set of constraints governing the phonological structure of syntactically free (i.e. inflected) lexical items. By this definition, all grammatical constructions which create phonological domains subject to the same set of constraints are 'word-level' (Bermúdez-Otero 1999: 74). Significantly, this definition does not carry an implication that the word level should be intralexical. In fact, under the split-morphology hypothesis (see e.g. Anderson 1982, 1988, 1992; Perlmutter 1988) regular inflection, which in keeping with our definition is typically word-level, is extralexical[29] and postsyntactic. In a split-morphology approach, therefore, it is unsurprising that some languages should choose to assign cliticization to the same phonological level as regular inflection. Both inflection and cliticization introduce syntactically functional but prosodically nonindependent material; in this sense, they contrast with nonclitic phrasing, which is similarly governed by the syntax but involves prosodically free material, and defines 'postlexical' domains in the familiar sense of the word (see footnote 31). The word-level behaviour of Catalan enclitics is also unproblematic in Orgun's (1996a, b) unification-based grammatical framework, where each morphological or syntactic construction is at liberty to select the corresponding cophonology.

The behaviour of *-ho* also indicates that, at the word level, Catalan permits onset-satisfying resyllabification across the right edge of the stem. Recall that this option is unavailable at the left edge. I therefore propose that ONSET dominates ANCHOR-R (the right-edge counterpart of ANCHOR-L) in the word-level constraint hierarchy. Interestingly, onset-maximizing resyllabification is unavailable at both edges. In (3.27e) the final consonant of the host surfaces as voiced before the initial liquid of accusative 3sg.fem. enclitic pronoun *-la*, in compliance with the postlexical requirement that coda obstruents should agree with the laryngeal specifications of a following onset consonant. Note, however, that spirantization fails to apply, indicating that the obstruent was subject to coda devoicing at the word level:

(3.29)	*rep-la*
Underlying representation	/rɛ𝔹-lə/
Stem level	[$_{\mathrm{PWd}}$.rɛb.]
Word level	
Cliticization	[$_{\mathrm{PWd}}$.rɛb.]lə
Prosodification	[$_{\mathrm{PWd}}$[$_{\mathrm{PWd}}$.rɛb.].lə.]
Devoicing	[$_{\mathrm{PWd}}$[$_{\mathrm{PWd}}$.rɛp.].lə.]
Postlexical level	
Spirantization	—
Voicing assimilation	.rɛb.lə.
	'receive her!'

29 Perlmutter (1988: 79) points out that the term 'extralexical' cannot be equated with 'postlexical', which in the Lexical Phonology tradition refers to phrase-level rules.

It follows that ANCHOR-R dominates CONTACT. This ranking persists into the postlexical module.

In sum, Catalan resyllabification is merely onset-satisfying, never onset-maximizing. At the right edge of the stem, resyllabification is active both at the word level and postlexically; at the left edge, in contrast, it only applies postlexically. To account for this pattern of prosodification I have proposed the following rankings:

(3.30) *Word level*: ANCHOR-L » ONSET » ANCHOR-R » CONTACT

Postlexical level: ONSET » ANCHOR-L, ANCHOR-R » CONTACT

This analysis is fully compatible with the claim that all coda obstruents undergo devoicing at the word level, thereby escaping postlexical spirantization. In fact, the premise that word-level devoicing is not a mere default process proves indispensable to understanding the failure of spirantization in prefix-final and pre-enclitic voiced obstruents (as in *sub-lunar* [su**b**.lu.nar] 'sublunar' and *rep-la* [rɛ**b**.lə] 'receive her', respectively). Moreover, I have demonstrated that enclitics can be analysed as word-level affixes, *pace* Harris (1993: 186-187).[30] This removes the motivation for three undesirable stipulations in Harris's analysis:

(i) the split of the postlexical module into two levels S1 and S2;
(ii) the assignment of devoicing to postlexical level S2, despite the fact that overapplication in nonclitic phrases points to the word as the real domain of devoicing;

and (iii) the extrinsic ordering of devoicing before resyllabification in S2.

Interestingly, Harris's (1993) stipulation that devoicing precedes resyllabification in S2 falls foul of Kaisse's (1999: 201) 'Syllabification First' principle, according to which all syllabification processes —including resyllabification— must apply before all other rules within a given stratum. In essence, this principle dictates that operations affecting prosodic affiliation must interact transparently with all other rules in the same cycle; a melodic process will never be counterfed or counterbled by the subsequent application of resyllabification within the same level. Kaisse's proposal is in all likelihood empirically correct; its only drawback is that, in a rule-based framework, it only holds by *fiat* and leads one to a dilemma. If stratum-internal opacity is permissible, why can it not involve syllabification? Conversely, if there is indeed no opacity within cycles, why should one countenance phonological rules at all, as opposed to constraints? Interleaved OT does not face this quandary, for the effects of 'Syllabification First' obtain without stipulation: since phonological mappings are strictly parallel in each cycle, there cannot be cycle-internal opacity.

3.4. The segment-rich lexicon, the stem level, and devoicing

In the previous section I have dealt with the peculiarities of Catalan syllabification as they impinge upon obstruent voicing and continuancy. A full account of word-level devoicing must also include a formal answer to another pressing question. In table (3.2) we saw that the devoiced allophones of /𝔹, 𝔻, 𝔾/ tolerate a single value for continuancy: viz. [-continuant]. Underlying /𝔹, 𝔻, 𝔾/, however, are rich in continuancy specifications: i.e., as stated in (3.5), *β* is a possible UR for /𝔹/, *ð* is a possible UR for /𝔻/, and *ɣ* is a possible UR for /𝔾/. This

[30] According to Kaisse (1999: 201), Harris has of late come to countenance this possibility.

implies that surface [p, t, k] may derive from continuant underliers, whilst underlying *β*, *ð* and *ɣ* cannot be mapped onto voiceless fricatives. Why should the neutralization of voice contrasts affect continuancy in precisely this manner?

It goes without saying that this question only arises in a framework committed to Richness of the Base. Pre-OT phonology countenanced the possibility of directly imposing constraints upon underlying representations; see diagram (1.30) in Archangeli (1997: 27). Thus, traditional analyses simply stipulate that, underlyingly, the nonsibilant voiced obstruents of Catalan are stops, i.e. /b, d, g/ (§x.x.x); the fact that their devoiced allophones are [p, t, k] would simply reflect the preservation of [cont] specifications under voice neutralization. In OT, however, this account cannot be maintained because the theory has no means of expressing constraints on the input of a mapping and, by implication, on underlying representations. As Tesar & Smolensky (2000: 74) put it, “the set of possible inputs to the grammars of all languages is the same”. In other words, no optimality-theoretic analysis can assume the existence of a systematic gap in the lexicon which is then simply transferred onto the output via faithfulness; whatever systematic gaps appear on the surface must rather be accounted for in terms of the satisfaction of markedness constraints. To determine the actual shape of underlying representations in the speaker's mental dictionary, Lexicon Optimization presupposes that an adequate grammar is already in place which guarantees the absence of illegal structures from the output (§x.x.x). In this sense, traditional analyses of Catalan devoicing depend upon the exclusion of [β, ð, ɣ] from underlying representations; under Richness of the Base this expedient is categorically forbidden.

In section x.x.x I shall prove that strictly parallel implementations of OT come to grief over the Catalan facts. If continuancy-rich /𝔹, 𝔻, 𝔾/ are to be directly mapped onto surface [p, t, k] in devoicing environments, then one must establish a ranking of constraints such that the mappings *β*—>[ɸ], *β*—>[f], *ð*—>[θ], *ð*—>[s] and *ɣ*—>[x] are nonoptimal, despite the fact that they are continuancy-preserving. Reliance on output markedness constraints is only possible in the case of /𝔾/, for [f] and [s] are possible surface segments in Catalan and are moreover free to occur in the devoicing environment. This implies that some form of faithfulness must be involved in blocking *β*—>[f] and *ð*—>[s]. Invoking faithfulness to underlying stridency specifications, however, only works for coronal /𝔻/, which contrasts in stridency with /z/. In the case of labial /𝔹/, I will show that it is rich in stridency values: i.e. both nonstrident *β* and strident *v* can instantiate /𝔹/ in the input. Thus, Catalan presents parallelist OT with an empirical challenge of a type which has hitherto escaped notice: a Richness-of-the-Base paradox. On the one hand, the underlying labial voiced obstruent cannot be simultaneously rich in continuancy and stridency specifications: if *v* occupies the place of /𝔹/ in the underlying representation, there is no way of outlawing the incorrect mapping /𝔹/—>[f] in devoicing environments and of enforcing /𝔹/—>[p]. On the other hand, one cannot avoid the conclusion that /𝔹/ *must* be rich both in continuancy and in stridency specifications: its noncontinuant allophones [b] and [p] are in complementary distribution with the continuant variant [β], and, at the same time, the nonstrident realization [β] is in complementary distribution with strident [v], the voiced allophone of /f/.

In this section, however, I shall demonstrate that interleaved OT can model the effects of the traditional approach to Catalan coda devoicing whilst strictly observing Richness of the Base. I have established that devoicing applies at the word level. The input to the word level, however, is identical with the output of the stem level; accordingly, it is nonrich, but will contain systematic gaps enforced by high-ranking markedness constraints at the stem level. It is therefore perfectly legitimate to assume that [β, ð, ɣ] are absent from the input to coda devoicing; to achieve this state of affairs, one need only promote the appropriate markedness constraints in the stem-level hierarchy. In this sense, the received view of Catalan devoicing is essentially right, insofar as the devoiced word-level allophones [p, t, k] are derived from the stem-level stops [b, d, g] with simple preservation of continuancy specifications. Richness of the Base still holds sway over the underlying representation, which contains continuancy-rich /𝔹, 𝔻, 𝔾/. Furthermore, our solution is nonstipulative, for continuancy played no rôle at all in the ascription of devoicing to the word level: the crucial datum was the overapplication of devoicing to word-final obstruents resyllabified before vowel-initial nonenclitics.

Let us now formalize this solution. I have asserted that, at the stem level, underlying /𝔹, 𝔻, 𝔾/ are mapped onto the voiced stops [b, d, g]; nonspecified [B, D, G] and continuant [β, ð, ɣ] are thus systematically absent from the input to the word level. We may safely assume that [B, D, G] are ruled out by a high-ranking markedness constraint against continuant-nonspecification; this just leaves the absence of [β, ð, ɣ] to be accounted for. I propose that that the constraint responsible for banning the voiced continuants is VFP; see (3.7) above. Its ranking with respect to VSP will be the opposite of that holding in the postlexical module. Let us therefore adopt (3.31) as a first approximation; cf. (3.8).

(3.31) IDENT[Lar] VFP

IDENT[cont] VSP

Tableau (3.32) shows how this hierarchy implements the mapping /𝔹/—>[b]. Note that the content of the cells for inactive IDENT[cont] is left indeterminate: the actual marks will depend on the particular instantiation of /𝔹/ in the input; see (3.5) for the available choices. These marks do not matter in any case, because higher-ranked constraints suffice to select the optimal candidate. Henceforth I shall use the long dash in tableaux to indicate the indeterminate score awarded by an inactive, crucially dominated, faithfulness constraint FAITH[F] to a candidate *c* when *c* is rich in specifications for [F].

(3.32)

Stem level		IDENT[Lar]	VFP	IDENT[cont]	VSP
𝔹	f	*!		—	
	p	*!		—	
	β		*!	—	
	b <—			—	*

Nonetheless, the hierarchy in (3.31) poses a significant problem. High-ranking VFP penalizes all voiced fricatives, yet the phonemes /z/ and /ʒ/ escape fortition. The reason for their privileged status is, however, not hard to find: /z/ and /ʒ/ are sibilants, of which Catalan possesses a full set; see chart (3.1). Sibilants are widely acknowledged as forming a natural class (Ladefoged 1993: 167-168); indeed, Ladefoged & Maddieson (1996: 138, 180) treat sibilance as the major classificatory dimension among fricatives. I therefore assume that VFP is outranked by a faithfulness constraint demanding the preservation of sibilance:

(3.33) **IDENT[sibilant]**

Let α be a segment in the input.
Let β be a correspondent of α in the output.
If α is sibilant, then β is sibilant.
If α is nonsibilant, then β is nonsibilant.

Definition: sibilant $=_{def}$ [Coronal, +strident]
nonsibilant $=_{def}$ ¬[Coronal, +strident]

As (3.33) indicates, sibilance is not a phonological feature but a property of segments calculated in terms of place and stridency (*pace* Ladefoged & Maddieson 1996: 180; see Clements & Hume 1995: 293-294): coronal stridents are sibilant; all other segments are nonsibilant.[31] As for [strident], I assume that only [-son, +cont] segments can bear specifications for this feature (Spencer 1996: 111); this restriction may be regarded as part of the universal theory of linguistic representations resident in GEN. In this sense, /z/ and /ʒ/ can faithfully realize their underlying sibilance only if they remain coronal and strident, and they can only remain strident if they remain fricative.

The appeal to IDENT[sibilant] presupposes that /z/ and /ʒ/ are distinctively [+strid] and hence sibilant. /𝔻/, in contrast, is distinctively nonsibilant by virtue of not being [+strid]. To verify this last assertion, recall that /𝔻/ = {D, d, ð}. Within this set, *ð* is [-strid]; in turn, *D* and *d* cannot support [+strid] because neither is [+cont]. Table (3.34) shows how the sibilance or nonsibilance of voiced coronal obstruents is computed on the basis of their featural content in accordance with the definitions stated in (3.33):

31 Sonority is another property of segments which is not expressed as a feature, but is computed on the basis of featural content: see e.g. Clements (1992: 64-65), Blevins (1995: 211).

(3.34) **Featural content and sibilance in voiced coronal obstruents**

	/𝔻/			/z/
	D	*d*	*ð*	*z*
Place	Cor	Cor	Cor	Cor
[continuant]	0	-	+	+
[strident]	0	0	-	+
sibilant?	✗	✗	✗	✓

The stridency contrast between /z/ and /𝔻/ is justified by minimal pairs such as *podar* [puða] 'to prune' vs *posar* [puza] 'to put down', where both segments have identical values for all other features. Tableau (3.35) shows how IDENT[sibilant] discriminates between /z/ and /𝔻/, preserving the former from hardening.

(3.35)

Stem level		ID[sibil]	ID[Lar]	VFP	VSP	ID[cont]	ID[strid]
𝔻	s	*!	*!			—	*
	z	*!		*		—	*
	t		*!			—	—[32]
	θ		*!			—	—[33]
	ð			*!		—	—[33]
	d <—				*	—	—[33]
z	t	*!	*!			*	*
	θ	*!	*!				*
	d	*!			*	*	*
	ð	*!		*			*
	s		*!				
	z <—			*			

[32] Recall that /𝔻/ is not [+strid], but is indeterminate between [-strid] and [0strid]; see table (3.34).

This tableau also shows that high-ranking IDENT[sibilant] can protect the voiced fricatives /z/ and /ʒ/ from stopping, but not from devoicing. To block the latter, it is necessary to rank IDENT[Laryngeal] above VFP. This turns out to be a very welcome result. Underlying *β, ð* and *ɣ* could in principle be eliminated from the stem-level representation through devoicing rather than hardening. Although I have hitherto tacitly ignored this scenario, it is not theoretically inconceivable, for we have so far encountered no alternations targeting underlying nonsibilant voiced obstruents at the stem level. In fact, the ranking {IDENT[cont], VFP} » IDENT[Lar] » VSP would map underlying *β, ð* and *ɣ* onto voiceless fricatives and leave *b, d* and *g* unchanged; cf. (3.31).[33] In practice, however, the ranking VFP » IDENT[Lar] is unviable, as it would neutralize the contrast between voiced sibilants and their voiceless counterparts. In this sense, the existence of a phonemic voice contrast among the Catalan sibilants confirms the ranking of IDENT[Lar] over IDENT[cont], as hypothesized in (3.31).

Interestingly, tableau (3.35) further indicates that IDENT[strid] must be ranked below VFP. When /𝔻/ is instantiated by *ð* in the underlying representation, the result is the stem-level mapping *ð*—>[d]. This mapping involves unfaithfulness in terms of stridency, for input *ð* is [-strid] whilst output [d] is [0strid]; see table (3.34). Avoiding [ð] in the output is thus more important that preserving underlying [-strid]. The same line of reasoning applies to labials and dorsals: the mappings *β*—>[b] and *ɣ*—>[g] are unfaithful in respect of IDENT[strid] in that the input is [-strid] but the output cannot support this specification; accordingly, they require the ranking VFP » IDENT[strid]. Of course, this argument is valid only if stridency oppositions are equipollent rather than privative, as I have assumed so far; if [strident] were a unary feature, then there would be no distinction between the values [-] and [0].

Even though one may challenge the equipollence of stridency contrasts,[34] the ranking VFP » IDENT[strid] still makes a very important prediction. The voiced fricatives *v* and *ʁ* are strident but noncoronal. Accordingly, they do not enjoy the protection of IDENT[sibilant] against VFP. Therefore, if VFP dominates IDENT[strid], then underlying *v* and *ʁ* will suffer

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[33] In principle, devoicing of *β, ð* and *ɣ* would yield [ɸ, θ, x]. None of these segments is tolerated in Standard Catalan, but [ɸ] and [θ] could conceivably have their stridency adjusted so as to merge with /f/ and /s/. Dorsal [x] would still have to be eliminated in some other way: Catalan lacks dorsal and pharyngeal fricatives altogether, nor does it possess [h]; see the allophone table in Recasens (1991: 172). As we shall see below, [θ] and [x] can be found in unassimilated borrowings from Castilian Spanish, but they are replaced by [s] and [k] in nativized loans (Hualde 1992: §3.1.2.3).

[34] For our present purposes, for example, treating [strident] as a unary feature would considerably simplify the analysis of postlexical spirantization. In general, nonstrident fricatives are marked in comparison with their strident counterparts (see below); yet spirantization produces nonstrident segments, viz [β, ð, ɣ]. If stridency oppositions were privative, however, this effect could be attributed to IDENT[strid]: postlexical [β, ð, ɣ] would just be faithful to the absence of [strident] in their word-level input correspondents [b, d, g]. In contrast, if [strident] is a binary feature, then both [+strid] and [-strid] continuants violate IDENT[strid] in respect of [0strid] stops. In that case, surface [β, ð, ɣ] will have to be seen as inheriting whatever other features mark [b] as bilabial rather than labiodental, [d̪] as dental rather than alveolar, and [g] as velar rather than uvular. In the case of [g], one could rely on [-high]; in that of [d], on [+distributed]. The case of [b] is less clear: there is little evidence of a phonological distinction between bilabial and labiodental stops, although such a contrast is reported to exist in languages of Southern Africa (Ladefoged & Maddieson 1996: 17-18).

the same fate as their nonstrident counterparts *β* and *ɣ*: they will be mapped onto the stops [b] and [g].[35] By implication, *v* ∈ /𝔹/ and *ʁ* ∈ /𝔾/; or, to put it differently, /𝔹/ and /𝔾/ are, unlike /𝔻/, rich in stridency specifications.

(3.36)

Stem level		ID[sibil]	ID[Lar]	VFP	VSP	ID[cont]	ID[strid]
v	p		*!			*	*
	ɸ		*!				*
	f		*!				
	β			*!			*
	v			*!			
	b ☞				*	*	*
ʁ	k		*!			*	*
	x		*!				*
	χ		*!				
	ɣ			*!			*
	ʁ			*!			
	g ☞				*	*	*

This prediction turns out to be correct. In section x.x.x we saw that the only source of surface [v] in Standard Catalan is underlying /f/ through postlexical assimilatory voicing. Since there is no other voicing process at either the stem or the word level, it follows that [v] is absent until then. The assertion that underlying *v* maps onto something else at the stem level, viz. [b], must therefore be correct. Additionally, [ʁ] never occurs on the surface; as predicted above, therefore, every token of underlying *ʁ* must merge with some other segment at some point; as it happens, it merges with /𝔾/ at the stem level. In the case of input *v*, moreover, we have independent external evidence to prove that it merges with /𝔹/ and not with something else. Of course, *v* could not retain its stridency by devoicing to [f] because IDENT[Lar] dominates VFP, but it could conceivably merge with sibilant /z/ under the ranking IDENT[strid] » IDENT[sibilant] » {VFP, IDENT[Place]}. The historical and dialectal evidence,

[35] This applies to the majority of Catalan dialects. Recall, however, that *v* remains phonemic over a substantial area including the Balearics, the Camp de Tarragona, and parts of Valencia. Additionally, the treatment of *ʁ* may be different in the dialect of the Roussillon, where [ʀ] and [ʁ] are found as allophones of the rhotic phonemes, particularly /r/, under French influence (Recasens 1991: 325).

however, shows this ranking to be incorrect: in those dialects where distinctive /v/ is being lost, the phoneme is merging with /𝔹/ rather than /z/ (Recasens 1991: 195-196).

We can still push Richness of the Base a bit further. If /𝔹/ is rich in stridency specifications, its opposition to /f/ must depend on [voice] rather than on [strident]. By the same token, the voiceless labial fricative phoneme will itself be rich in stridency: i.e. /𝔽/ = {F, f, ɸ}, where *F* stands for a voiceless labial fricative unspecified for stridency. This will not affect its contrast with /p/, which is based on continuancy. However, we know that the two surface allophones of /𝔽/ are [+strid]: viz. [f] and [v]; additionally, [v] does not appear until the postlexical module. We must therefore engineer the stem-level constraint hierarchy so that stridency-rich /𝔽/ is mapped onto [f]. This proves easy to do. The two outlawed competitors of [f], viz. [ɸ] and [F], fail to carry the specification [+strid]. Since nonstrident [β, ð, ɣ] are also absent from the stem-level output *ex hypothesi*, the net result is that all the fricatives present at this stage in the derivation, viz. [f, s, z, ʃ, ʒ], are [+strid]. This indicates that IDENT[strid] is dominated by a top-ranked markedness constraint requiring that all fricatives should be strident.

(3.37) **FRIC—>STRID**

If a segment is [-son, +cont], then it must be [+strid].

FRIC—>STRID is grounded on the greater acoustic salience of strident fricatives as compared with their nonstrident counterparts.[36]

(3.38)

Stem level		FRIC—>STRID	IDENT[cont]	IDENT[strid]
𝔽	p		*!	—
	F	*!		—
	ɸ	*!		—
	f <—			—

The ranking of IDENT[cont] over IDENT[strid] blocks the mapping *F*—>[p]. Under the alternative hierarchy FRIC—>STRID » IDENT[strid] » IDENT[cont], *F* would merge with [p], which supports no stridency specifications at all, whilst *f* and *ɸ* would map onto [f]. Independent support for the ranking IDENT[cont] » IDENT[strid] will be provided presently.

[36] One might object that the absence of [β, ð, ɣ] from the stem level is now overdetermined, as these segments violate both VFP and FRIC—>STRID. This objection would be misguided. Whilst VFP and FRIC—>STRID do overlap in respect of [β, ð, ɣ], the former is active in banning [v] and [ʁ], which satisfy FRIC—>STRID, whilst the latter is responsible for excluding [ɸ], which passes VFP. Additionally, only VFP can guarantee that *ð* exits the stem level by hardening to [d], rather than by adjusting its stridency to [z]; see tableau (3.39) below.

Undominated FRIC—>STRID not only guarantees that stridency-rich /𝔽/ is realized as [f], but also removes all instances of [θ] from the output of the stem level. Interestingly, we have external evidence to show that underlying *θ* merges with /s/. As reported by Hualde (1992: §3.1.2.3), [θ] occurs in a number of Castilian Spanish words borrowed into Catalan; when such loans become nativized, [s] is substituted. Crucially, replacement by [t̪] does not occur. This indicates that preserving the continuancy of the Castilian source is more important than retaining its dentality. We can capture this fact by ranking IDENT[cont] over IDENT[strid] at the stem level.[37] There is, however, one further problem: IDENT[sibilant], which I relied on to preserve /z/ and /ʒ/ from hardening, incorrectly blocks the mapping *θ*—>[s]. It therefore appears that changes in sibilance are avoided only when they accompany a change in continuancy; in other words, the phonology allows a nonsibilant fricative to become sibilant and vice versa, but prevents sibilants to be mapped onto stops in one fell swoop. Formally, this implies that IDENT[sibilant] is locally conjoined with IDENT[cont]. Tableau (3.39) shows how the conjunctive constraint IDENT[sibilant]&IDENT[cont] allows nonsibilant *θ* to merge with sibilant [s], whilst correctly preventing the stopping of /z/ and /ʒ/.

[37] Under this proposal, unassimilated borrowings, such as those retaining Castilian [θ], are characterized by their failure to undergo the native stem-level phonology. This effect may be achieved through level prespecification (Inkelas & Orgun 1995: §7). Essentially, a nonnativized loan is stored in memory as a ready made 'P-stem' with its stem-level phonology precomputed; being prespecified as a P-stem, the item is able to skip the stem level and to enter the word level directly.

(3.39)

Stem level			ID[sibil]&ID[cont]	FRIC—>STRID	VFP	VSP	ID[cont]	ID[sibil]	ID[strid]
/𝔻/	*d*	d ☞				*			
		ð		*!	*		*		*
		z	*!		*		*	*	*
	ð	d ☞				*	*		*
		ð		*!	*				
		z			*!			*	*
	D	d ☞				*	*		
		ð		*!	*		*		*
		z	*!		*		*	*	*
/z/	*z*	d	*!			*	*	*	*
		ð		*!	*			*	*
		z ☞			*				
/𝕊/	*θ*	t					*!		*
		θ		*!					
		s ☞						*	*

In contrast with *θ* and *ɸ*, dorsal *x* has no strident fricative to merge with: Catalan does not tolerate [χ]. I assume this gap to be due to a top-ranked constraint against dorsal fricatives: see (3.40). Crosslinguistically, dorsal fricatives are rarer than labials or coronals (see Maddieson 1984: 45). This is also in harmony with the place markedness hierarchy *DOR » * LAB » *COR.

(3.40) ***DORFRIC**

*[Dorsal, -sonorant, +continuant]

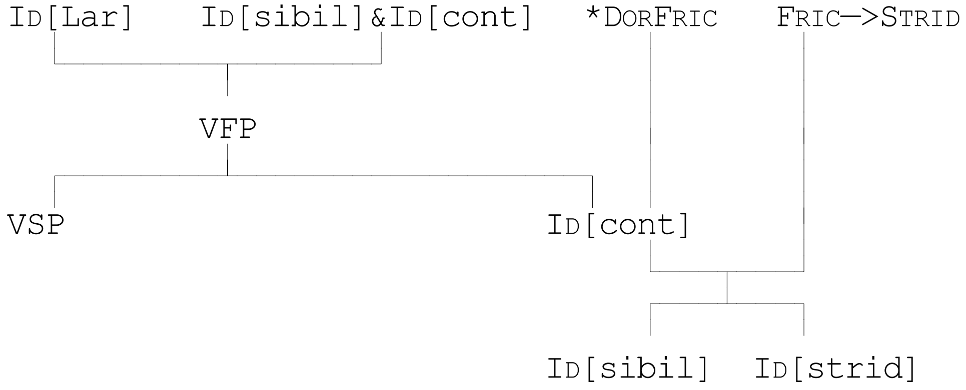
*DORFRIC leaves *x* no choice other than to merge with the only voiceless dorsal obstruent permitted in Catalan: viz. [k]. This result is confirmed by the fact that Spanish /x/ turns up as [k] in nativized loans: e.g. Spanish [maxo] —> Catalan [maku] 'nice' (Hualde 1992: 378).

This concludes my analysis of the obstruent system of Catalan at the stem level. Since the foregoing argument is somewhat intricate, I shall now summarize its main steps:

- The argument starts with the observation that the word-level devoicing of /𝔹, 𝔻, 𝔾/ yields stops rather than continuants.
- Following traditional approaches to the phonemic inventory of Catalan, I hypothesize that devoicing is continuancy-preserving: underlying /𝔹, 𝔻, 𝔾/ are realized as noncontinuant [b, d, g] at the stem level; at this stage, [β, ð, ɣ] are excluded.
- The exclusion of [β, ð, ɣ] is effected by high-ranking VFP, which dominates IDENT[cont].
- /z/ and /ʒ/ are shielded from the hardening effect of VFP by IDENT[sibilant]. This constraint exploits the stridency contrast between coronal /z/ and /𝔻/.
- Since IDENT[sibilant] cannot stop /z/ and /ʒ/ from satisfying VFP through devoicing, one further concludes that VFP is dominated by IDENT[Lar]. This confirms that underlying *β, ð,* and *ɣ* are subject to stopping, rather than devoicing.
- As the next step, I note that, if stridency oppositions are equipollent, then the mapping *ð*—>[d] violates IDENT[strid], as *ð* will be marked as [-strid], whilst [d] cannot support stridency specifications. From this observation I derive the ranking VFP » IDENT[strid].
- The ranking VFP » {IDENT[strid], IDENT[cont]} predicts that the noncoronal strident fricatives *v* and *ʁ*, which are present in the segment-rich lexicon, also merge with [b] and [g]. In the case of *v*, our prediction receives independent support from diachronic and dialectal evidence.
- In turn, the stem-level mappings *v*—>[b] and *ʁ*—>[g] imply that, unlike /𝔻/, noncoronal /𝔹/ and /𝔾/ are rich in stridency specifications.
- The fact that /𝔹/ is stridency-rich further entails that the contrastive voiceless labial fricative is itself rich in stridency specifications: i.e. /𝔽/ = { F, f, ɸ }.
- For independent reasons, /𝔽/ must map onto strident [f]. This result is achieved by ranking FRIC—>STRID over IDENT[strid].
- Superordinate FRIC—>STRID also forbids [θ]. However, external evidence shows that nonsibilant *θ* merges with sibilant /s/ rather than with the stop /t/. This indicates that IDENT[sibilant], the constraint which protects /z/ and /ʒ/ from hardening, is locally conjoined with IDENT[cont].
- Finally, *DORFRIC prohibits both nonstrident [x] and strident [χ], which merge with /k/.

In (3.41) I summarize the constraint rankings which determine the stem-level inventory of obstruents in Catalan:

(3.41)



We now have an extremely detailed picture of how Catalan partitions a rich inventory of underlying obstruents into a few distinctive units, and of how these distinctive units are mapped onto the nonrich inventory of stem-level segments. I have by no means exhausted the possibilities of a segment-rich lexicon in OT: palatals and retroflexes have for example not been considered. Nor have I clarified all the intricacies of the Catalan obstruent system: affricates have been deliberately omitted, as their status is exceedingly problematic. Nonetheless, it is fair to say that inventorial analysis is rarely carried out with this degree of thoroughness in the optimality-theoretic literature. The special beauty of this case-study lies in its logical cohesion: a single premise, viz. that VFP bars [β, ð, ɣ] from the stem level, turns out to hold the key to virtually the entire system of Catalan obstruents.

Tables (3.42) and (3.43) provide a restatement of my results in synoptic format. In table (3.42) I have listed the obstruent phonemes of Catalan, excluding the palatoalveolars and the affricates. The table shows the feature values on which their mutual oppositions depend. A shaded cell indicates that the phoneme cannot bear specifications for the corresponding feature; this possibility arises with distinctively noncontinuant segments, which cannot support [strident]. Empty cells, in turn, denote specifications in which the phoneme is rich. I have used brackets to notate a noncontrastive feature value in respect of which the relevant phoneme is nonrich; this possibility arises in the case of /z/, which is contrastively [+strident] and is therefore predictably [+continuant].

(3.42) **Contrastive specifications of the Catalan obstruent phonemes**

	/p/	/𝔹/	/𝔽/	/t/	/𝔻/	/𝕊/	/z/	/𝕂/	/𝔾/
Place	L	L	L	C	C	C	C	D	D
[continuant]	-		+	-		+	(+)		
[strident]					-/0		+		
[voice]	-	+	-	-	+	-	+	-	+

Table (3.43) lists a representative subset of the obstruents contained in an optimality-theoretic segment-rich lexicon. Each segment is shown below the particular Catalan phoneme which would be instantiated by it. The stem-level correspondent assigned by hierarchy (3.41) to each underlying segment appears on the bottom row. Of course, the actual (nonrich) underlying representations stored in the minds of Catalan speakers will not contain all these segments; those predicted to occur by Lexicon Optimization are highlighted in boldface. It will be seen that they are identical with their stem-level correspondents: they thus avoid violating faithfulness constraints at the stem level; all other alternatives incur some extra faithfulness penalty.

Interestingly, interleaved OT turns out to provide a very traditional picture of the composition of Catalan underlying representations: the inventory of underlying obstruents selected by Lexicon Optimization coincides in every respect with the list of phonemes set out in chart (3.1). The innovation, of course, lies elsewhere. The arrow of explanation has been reversed: the operation of the grammar no longer depends on the idiosyncrasies of the lexicon; rather, the content of underlying representations is determined by the ranking of markedness and faithfulness constraints in the grammar, particularly at the stem level. In this sense, hierarchy (3.41) does not presuppose the set of contrasts laid out in (3.42), but actually predicts both (3.42) and (3.43).

(3.43) **Inventory of underlying and stem-level obstruents in Catalan**

Underlying segment	Distinctive unit / /	p	𝔹					𝔽			t	𝔻				𝕊			z	𝕂					𝔾				
	Instantiations	**p**	**b**	β	v	B	V	**f**	ɸ	F	**t**	**d**	ð	D	Z	**s**	θ	S	**z**	**k**	x	χ	K	X	**g**	ɣ	ʁ	G	Y
Featural content	Place	L	L	L	L	L	L	L	L	L	C	C	C	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D
	[continuant]	-	-	+	+	0	+	+	+	+	-	-	+	0	+	+	+	+	+	-	+	+	0	+	-	+	+	0	+
	[strident]	0	0	-	+	0	0	+	-	0	0	0	-	0	0	+	-	0	+	0	-	+	0	0	0	-	+	0	0
	[voice]	-	+	+	+	+	+	-	-	-	-	+	+	+	+	-	-	-	+	-	-	-	-	-	+	+	+	+	+
	Sibilant?	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Stem-level correspondent		p	b					f			t	d				s			z	k					g				

3.5. Voice neutralization

The two previous sections have cleared the ground for an optimality-theoretic analysis of Catalan devoicing and voice assimilation. In §x.x.x I dealt with syllabification constraints at the word and postlexical levels; these determine exactly which obstruents occupy the coda, becoming subject to laryngeal neutralization. In §x.x.x, in turn, it was shown that the stem-level hierarchy maps continuancy-rich /𝔹, 𝔻, 𝔾/ onto the stops [b, d, g]; this accounts for the fact that their devoiced allophones are noncontinuant. This section will focus on the constraints responsible for the neutralization of voice oppositions. The discussion will proceed as follows. First, I shall briefly examine current theoretical proposals on the status of laryngeal features and the inventory of constraints regulating their distribution. I will then establish constraint rankings for word-level devoicing and postlexical voice assimilation. The analysis will prove mostly straightforward, but fricatives and affricates will be seen to raise particular problems, as they undergo assimilatory voicing in onset position when subject to postlexical resyllabification. I shall sketch two alternative solutions to this problem, neither of which interferes with the basic claim that the absence of postlexical spirantization in rhymes is caused by laryngeal neutralization in the coda at the word level.

3.5.1. The constraints

Laryngeal neutralization has received a great deal of attention in OT (particularly in the work of Linda Lombardi: see e.g. Lombardi 1999). There is an extensive literature on the set of constraints involved, but the issue is somewhat complicated by a concurrent debate on whether the feature [voice] is unary or binary. To capture the fact that voiceless obstruents are unmarked in relation to their voiced counterparts, most analysts rely on VOP (Itô & Mester 1998; Kager 1999: 40). As pointed out in §x.x.x, however, dealing with the facts of Catalan requires that VOP should be split into two subconstraints, VSP and VFP, which respectively target stops and fricatives; see (3.6) and (3.7). Lombardi (1999: 271) suggests that the function of VOP can be discharged by *LAR, a constraint forbidding laryngeal specifications; this proposal relies on the assumption that voicing contrasts are privative, so that voicelessness simply results from the absence of the laryngeal element [voice] (Mester & Itô 1989; Cho 1990a, b; Lombardi 1991, 1995b). Lombardi's suggestion meets with a number of problems. First, Mascaró & Wetzels (2000) have launched a vigorous attack on its basic premise; they argue that in a number of languages [-voice] is active for assimilation and dissimilation purposes, both lexically and postlexically. In the present context, *LAR would prove inadequate, for we have already found evidence that Catalan assesses voiced obstruents differently according to their continuancy values.

Any form of laryngeal neutralization implies that IDENT[Lar] is crucially dominated:

(3.44) **IDENT[Lar]**

Let *a* be a segment in the input.
Let *b* be a correspondent of *a* in the output.
The laryngeal specifications of *b* are identical with those of *a.*

As stated in (3.44), IDENT[Lar] is neutral between the unary and binary conceptions of the [voice] feature, and works whether or not a laryngeal node is assumed to be present in feature geometry (Lombardi 1999: 70).

Following the concept of positional faithfulness developed by Beckman (1997a, b), IDENT[Lar] can be relativized to onset positions:

(3.45) **ONSIDENT[Lar]**

Let α be a segment in the input.
Let β be a correspondent of α in the output.
Let β be in onset position.
The laryngeal specifications of β are identical with those of α.

ONSIDENT[Lar] captures the fact that onset consonants are typically resistant to laryngeal neutralization, and that coda-onset clusters normally undergo anticipatory rather than perseverative assimilation. A number of authors (e.g. Steriade 1993, 1994; Padgett 1995) have suggested that resistance to neutralization is in fact a property of released consonants, rather than of those in onset position; in this view, heightened featural faithfulness arises from the salient acoustic cues provided during the release phase of a consonantal constriction. Lombardi (1991, 1995a, 1999) accommodates these proposals by relativizing IDENT[Lar] to environment (3.46), where the target consonant both occupies the onset and is released onto a following sonorant:

```
(3.46)      σ
           / \
        ____  [+son]
```

This refinement is immaterial for our purposes, as in Catalan all onset obstruents happen to meet condition (3.46). Unlike Lombardi, however, Padgett (1995) argues for the stronger claim that positional faithfulness constraints should directly refer to released vs unreleased positions, bypassing prosodic structure. If this proposal were to be adopted, one would need to specify that all Catalan coda consonants are unreleased, even word-finally and before sonorants: note that, whilst Catalan supports a voice contrast among stops in pre-liquid onset position (see (3.54) below), it enforces laryngeal neutralization among preliquid obstruents syllabified in the coda (Mascaró 1987: 274; Mascaró & Wetzels 2000: note 21; see also §x.x.x above).

The constraints I have introduced so far account for obstruent devoicing and for the absence of laryngeal neutralization in onsets. There remains the fact that neutralization can be effected through assimilation. This raises the problem that the product of neutralization can be a marked voiced obstruent if it so happens that the assimilatory trigger is voiced. The current optimality-theoretic literature provides two alternative answers to this question (see Padgett 1995). One possibility is to deploy the traditional notion of prosodic licensing (Itô 1986) along the lines of (3.47):

(3.47) **LICENSE[Lar]**

A laryngeal node must not be licensed by a root node syllabified in the coda.

High-ranking LICENSE[Lar] prevents coda obstruents from supporting a laryngeal node; as a result, such obstruents may be compelled to borrow the laryngeal node licensed by a following onset consonant, even if this happens to be voiced. Of course, this account assumes that obstruents can be independently required to bear a laryngeal node, either by GEN or by a high-ranking constraint such as (3.48):

(3.48) **OBS—>LAR**

If a segment is [-sonorant], then it must possess a laryngeal node.

Hereafter I assume that in Catalan OBS—>LAR is top-ranked at all grammatical levels. Note that, in this context, postulating an obligatory laryngeal node is tantamount to setting up a representational distinction between voicelessness and voicing underspecification, even if the feature [-voice] is deemed not to exist:[38]

(3.49) **Three-way laryngeal contrast with unary [voice]**

```
Voiced        Voiceless     Unspecified

 root          root          root
  |             |
 Lar           Lar
  |
[voice]
```

This sort of three-way distinction is essential to the licensing-based approach to assimilation: assimilation is regarded as allowing segments with restricted licensing potential to avoid nonspecification, but, since assimilation can result in voicelessness, it follows that nonspecification and voicelessness must be representationally distinct.

In this sense, LICENSE[Lar] is trivially compatible with the treatment of [voice] as unary, as shown in (3.49), but preserves little of the spirit of privative theory, whose essential claim is that voicelessness consists of the absence of specifications for voice. As mentioned above, however, Mascaró & Wetzels (2000) argue that voice contrasts must in fact be equipollent. They point out that assimilation need not spread both values of [±voice], as in Catalan; the application of spreading may be limited to [+voice] or, crucially, to [-voice]. As evidence for leftward spreading of [+voice], Mascaró & Wetzels adduce Ukrainian assimilation: Ukrainian tolerates obstruent clusters with the profile [+voice][-voice], but forbids [-voice][+voice] sequences. In complete contrast, Ya:thê permits [-voice][+voice] clusters, but applies anticipatory [-voice] assimilation to remove all obstruent sequences where the first element is voiced and the second is voiceless.

(3.50) **Possible obstruent clusters in Ukrainian and Ya:thê according to [voice]**

Ukrainian	*Ya:thê*
− −	− −
+ +	+ +
*− +	− +
+ −	*+ −

[38] The representational system set out in (3.49) coincides with that assumed by Wagner (2000) in his analysis of laryngeal contrasts in the West Germanic family.

In a licensing-based analysis, such instances of single-value [voice] spreading seem to require that LICENSE should be allowed to select either [+voice] or [-voice] as its argument:

(3.51) **LICENSE[+voice]**

The feature [+voice] must not be licensed by a root node syllabified in the coda.

(3.52) **LICENSE[-voice]**

The feature [-voice] must not be licensed by a root node syllabified in the coda.

A particular value of [±voice] will display overt spreading behaviour when the opposite value is not licensed in coda position. In Ukrainian, for example, [+voice] spreads to coda obstruents because LICENSE[-voice] is active, disallowing [-voice] coda consonants whose laryngeal specifications are not supported by the following onset; this involves the hierarchy {ONSIDENT[Lar], LICENSE[-voice]} » IDENT[Lar] » LICENSE[+voice].[39] A licensing analysis could still be maintained if [voice] were regarded as unary, but in that case (3.52) would have to reformulated so as to refer to bare laryngeal nodes, i.e. laryngeal nodes dominating no features. In conclusion, the licensing approach to voice assimilation requires there to be a representational distinction between voicelessness and voicing underspecification; this proves not to be a disadvantage, in view of Mascaró & Wetzels's evidence for the noninertness of [-voice]. If one were to spouse a strictly unary conception of [voice], a representational contrast between voicelessness and voicing underspecification could still be maintained via the laryngeal node.

Conceptually, LICENSE[Lar] is also attractive in that it has the potential to induce neutralization in the coda whether or not a suitable assimilation trigger is present.[40] In this sense, it establishes a notional link between assimilation and default devoicing in terms of the weak licensing potential of coda consonants (Goldsmith 1990). This connection is enshrined in the classical rule-based autosegmental analysis of voice neutralization, in which delinking of [±voice] in the coda is followed either by spreading from the onset or by default insertion of [-voice]; see e.g. Mascaró (1987). Nonetheless, Baković (2000), quoting Lombardi's (1999) typology of voice neutralization, denounces this connection as spurious on the grounds that there is no crosslinguistic evidence for an implicational relationship between assimilation and default devoicing. In Yiddish and Romanian, for example, obstruent clusters are subject to assimilation, but there is no devoicing in environments where assimilation triggers are absent. Indeed, Catalan has both devoicing and assimilation, but the two processes apply at different levels in largely overlapping environments and cannot therefore be regarded as

[39] Curiously enough, under the licensing approach to assimilation it is the spreading of [+voice], rather than that of [-voice], that provides evidence to support the status of [-voice] as a phonological feature. The analysis of [+voice] spreading requires an active phonological constraint that mentions [-voice] specifically, declaring it to be unlicensed in the coda.

[40] I am grateful to Eric Baković for discussion of the matters raised in this paragraph.

complementary implementations of a single neutralization process.[41] Against Baković's argument, however, it must be noted that LICENSE[Lar] incurs no empirical difficulties over Lombardi's typology: the neutralization pattern of Yiddish and Romanian (i.e. assimilation without default devoicing) emerges from the ranking {ONSIDENT[Lar], OBS—>LAR} » LICENSE[Lar] » IDENT[Lar] » VOP.[42]

As an alternative to the LICENSE family, a number of authors countenance agreement constraints which specifically demand assimilation (Padgett 1995, Lombardi 1999, Baković 2000). Such constraints sever the connection between devoicing and assimilation altogether, and do not require a representational distinction between voicelessness and voicing underspecification. Lombardi (1999: 272), for example, posits a constraint requiring that obstruent clusters should agree in voicing (i.e., in her terms, in the presence or absence of the element [voice]). In the case of Catalan, however, Lombardi's constraint is obviously inadequate, for sonorants are capable of triggering assimilation just like obstruents; Mascaró & Wetzels (2000: note 4) cite Spanish and Sanskrit as behaving in a similar fashion. For our current purposes, therefore, we would need something like (3.53), where version (a) assumes the existence of a laryngeal node whilst version (b) remains noncommittal.

(3.53) **AGREE[LAR]**

(a) All consonants in a cluster must share the same laryngeal node.

(b) All consonants in a cluster agree in laryngeal specifications.

It would appear, however, that (3.53) endangers voice oppositions in obstruent+sonorant onset clusters. Catalan, for example, supports a contrast between /p, t, k/ and /𝔹, 𝔻, 𝔾/ in onset-initial position before liquids:

(3.54)	*plom* [plom] 'lead'	*blau* [blaw] 'blue'
	prim [pɾim] 'thin'	*bram* [bɾam] 'roar'
	tres [tɾɛs] 'three'	*drap* [dɾap] 'cloth'
	clar [kla] 'clear'	*glaç* [glas] 'ice'
	creu [kɾɛw] 'cross'	*grau* [gɾaw] 'degree'

Such distinctions could be preserved simply by ranking ONSIDENT[Lar] above AGREE[Lar]. Still, from a typological viewpoint it remains a troubling fact that the opposite ranking predicts voice assimilation within obstruent-sonorant clusters regardless of syllabification. Indeed,

41 As I warned in footnote (22) and shall demonstrate in §x.x.x, this conclusion cannot be regarded as unavoidable. Following Harris (1993), our approach to continuancy alternations in Catalan assumes that, in the rhyme, postlexical spirantization is bled by a word-level process of voice neutralization. However, this assumption is compatible with the idea that word-level coda obstruents are simply unspecified for voice, rather than voiceless. If one adopts this proposal, then the postlexical module reverts to the traditional régime of assimilation with default devoicing. As we shall see below, the question of whether rhymal obstruents are voiceless or laryngeally unspecified at the word level depends on one's analysis of the behaviour of prefix-final and word-final fricatives in prevocalic position.

42 In Mascaró's (1987) rule-based autosegmental framework, Yiddish and Romanian require the application of a rule of reassociation: see Mascaró (1987: 278).

under the hierarchy AGREE[Lar] » ONSIDENT[Lar] » VOP, it should be possible for a language to have a voice opposition among obstruents in prevocalic position, only to suspend it in favour of the marked term (i.e. voicing) in onset position before a sonorant consonant, whether the latter is syllabic or nonsyllabic (*pace* Lombardi 1999: 290-291).

(3.55) **Predictions of the hierarchy AGREE[Lar] » ONSIDENT[Lar] » VOP**

/ta/ —> [.ta.]	/tɾa/ ↘ [.dɾa.]	/tn/ ↘ [.dn̩.]
/da/ —> [.da.]	/dɾa/ ↗ [.dɾa.]	/dn/ ↗ [.dn̩.]

I know of no language which instantiates these predictions.

On theoretical grounds, in sum, one is inclined to prefer LICENSE to AGREE constraints. Accordingly, I shall take laryngeal neutralization patterns in general to be determined by dominance relationships within the following inventory:

(3.56) **Constraints on laryngeal contrasts**

Label	*Covering constraint*	*Statement*	
VSP	VOP	(3.6)	
VFP		(3.7)	
IDENT[Lar]		(3.44)	
ONSIDENT[Lar]		(3.45)	
OBS—>LAR		(3.48)	
LICENSE[+voice]	LICENSE[Lar]	(3.51)	(3.47)
LICENSE[-voice]		(3.52)	

At this point, the reader may feel that the relative simplicity of Catalan devoicing and assimilation hardly merits such lengthy theoretical deliberations. As we shall see presently, however, our exposition has so far sidestepped a minor but challenging wrinkle in the Catalan facts: at the postlexical level laryngeal neutralization is not entirely bound to the coda, for prefix-final and word-final fricatives undergo voicing when resyllabified into the onset. Since this phenomenon might be taken as *prima facie* evidence against an approach reliant on licensing, an assessment of its advantages in relation to AGREE-based alternatives was in order. Moreover, it turns out that, among other possibilities, one could easily account for the voicing of word-final fricatives in prevocalic position by assuming that the word-level neutralization of voice contrasts in the coda actually involves delaryngealization (i.e. loss of the laryngeal node) rather than devoicing. To put this proposal in its proper context, however, it was necessary to establish the credentials of equipollent approaches to voice as against privative theory.

3.5.2. The rankings

We are now in a position to determine the appropriate rankings in the grammar of Catalan. At the stem level the situation is straightforward: there is no neutralization of voice contrasts among obstruents. This fact was captured by the superordinate ranking of IDENT[Lar] in hierarchy (3.41); faithfulness to underlying laryngeal specifications dominates both VFP and VSP. To this one need simply add that IDENT[Lar] outranks LICENSE[Lar].

Coda devoicing springs into action at the word level. Recall that word-level devoicing targets all rhymal obstruents, whether or not there is a following onset containing a potential assimilation trigger (§x.x.x). Moreover, underlying /𝔹, 𝔻, 𝔾/ have at this stage undergone stopping to [b, d, g], and so their devoiced allophones are noncontinuant [p, t, k] (§x.x.x). Coda devoicing is brought about by the following hierarchy (see Lombardi 1999: 276 for an analogous analysis using AGREE):

(3.57) **Coda devoicing**

ONSIDENT[Lar]
|
VOP
/ \
LICENSE[Lar] IDENT[Lar].

Using examples introduced in diagram (3.18), the following tableau shows how ONSIDENT[Lar] protects the voice specifications of onset consonants, whilst VOP enforces obstruent devoicing elsewhere:

(3.58)

Word level		ONSID[Lar]	VOP	LICENSE[Lar]	ID[Lar]
.ʎob.	.ʎob.		*!	*	
	.ʎop. ☞			*	*
.ʎo.bə.	.ʎo.pə.	*!			*
	.ʎo.bə. ☞		*		

Since VOP dominates LICENSE[Lar], devoicing applies even if, as a result, a voiceless coda obstruent is prevented from sharing its laryngeal node with a following voiced onset consonant. This situation is illustrated in tableau (3.59b). Observe that in this example the target obstruent is assumed to be underlyingly rich in voice specifications because it never surfaces in a nonneutralizing position; we nevertheless know that it undergoes devoicing at the word level because it fails to spirantize postlexically (see §x.x.x, and diagram (3.19) in particular).

(3.59)

(a) *examen*

Underlying representation	/ə𝔾zamən/	or	/ə𝕂zamən/
Stem level	.əg.za.mən.		.ək.za.mən.
Word level	.ək.za.mən.		—
Postlexical level			
Spirantization	—		—
Assimilation	.əg.za.mən.		.əg.za.mən.
	‘examination’		

(b)

Word level		ONSID[Lar]	VOP	LICENSE[Lar]	ID[Lar]
.əg.za.mən.	.ək.sa.mən.	*!			**
	.əg.za.mən.		**!		
	.ək.za.mən. ☞		*	*	*
.ək.za.mən.	.ək.sa.mən.	*!			*
	.əg.za.mən.		**!		*
	.ək.za.mən. ☞		*	*	

Postlexically, coda obstruents undergo voice assimilation whenever followed by an onset consonant. Notably, this applies to all instances of input [p, t, k], whether derived from underlying /p, t, 𝕂/, or from underlying /𝔹, 𝔻, 𝔾/ by word-level devoicing. Assimilation applies vacuously when the trigger is voiceless, as the input to the postlexical level contains no voiced obstruents in coda position; in this case, the only effect of LICENSE[Lar] is to merge two identical laryngeal nodes (if the voiceless coda-onset cluster is not already Laryngeal-sharing). Both obstruents and sonorants qualify as assimilation triggers, which implies that Catalan sonorants are equipped with laryngeal nodes, at least at the postlexical level; we may assume that sonorants are laryngeally unspecified in languages where they are inert for voice assimilation. The process is governed by the following constraint hierarchy:

(3.60) **Coda assimilation**

ONSIDENT[Lar]   LICENSE[Lar]
        \   /   \
        VOP   IDENT[Lar]

The following tableau illustrates the nonvacuous implementation of this ranking:

(3.61) *llop gran* [ʎob.gɾan] ‘big wolf’

Postlexical level		ONSID[Lar]	LICENSE[Lar]	VOP	ID[Lar]
.ʎop. .gɾan.	.ʎop.kɾan.	*!			*
	.ʎop.gɾan.		*!	*	
	.ʎob.gɾan. ☜			**	*

3.5.3. Prevocalic prefix-final and word-final fricatives

As was demonstrated in section x.x.x, prevocalic prefix-final and word-final obstruents are in the coda at the word level, where they undergo devoicing, and become subject to onset-satisfying resyllabification postlexically. One would accordingly expect such obstruents always to surface as voiceless: the laryngeal specifications assigned to them at the word level would escape neutralization processes in the postlexical module. Stops fulfil this prediction, but fricatives behave unexpectedly, for they undergo voicing (Fabra 1912: §23α; Wheeler 1979: 310-313; Hualde 1992: 393-394):

(3.62) **Postlexical voicing of prevocalic prefix-final and word-final fricatives**

(a) *Prefix-final*

bes-avi	[bəzaβi]	‘great-grandfather’
des-agradar	[dəzəɣɾəda]	‘to displease’
sots-arrendar	[sodzərənda]	‘to sublet’
trans-acció	[tɾənzəksio]	‘transaction’

(b) *Word-final*

serf	[serf]	'serf'
serf ancià	[servənsia]	'elderly serf'[43]
discs	[disks]	'records'
discs antics	[dizgzəntiks]	'old records'
mateix	[mateʃ]	'same'
mateix home	[məteʒɔmə]	'same man'
gats	[gats]	'cats'
gats alats	[gadzəlats]	'winged cats'
boig	[bɔtʃ]	'madman'
boig estrany	[bɔdʒəstɾaɲ]	'strange madman'

The crucial factor inducing voicing in these circumstances appears to be the presence of a voiced segment immediately following the fricative. The phenomenon cannot be imputed to a constraint demanding that continuants should be voiced in intervocalic position (see e.g. Kager 1999: 325), for voicing occurs not only between vowels (e.g. *mateix home* [mət*eʒɔ*mə] 'same man') but also after consonants, whether sonorant (e.g. *serf ancià* [se*ɾv*ənsia] 'elderly serf') or nonsonorant (e.g. *discs antics* [diz*gz*əntiks] 'old records'). Similarly, voicing cannot be triggered by a constraint disallowing voiceless fricatives between voiced segments: such a requirement would be vacuously satisfied by the incorrect parse *[disksantiks] without unfaithfulness to word-level specifications. Indeed, in the example [dizg.zən.tiks] the voicing of the rhymal obstruent cluster [zg] is parasitic on that of the following word-final onset fricative (Fabra 1912: §23α; Wheeler 1979: 310); it simply reflects the application of ordinary laryngeal assimilation in the coda.[44] Finally, one could surmise that, regardless of their position in syllable structure, fricatives are simply unable to license their own laryngeal node and must accordingy share that of an adjacent legitimate licenser, where a following vowel,

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[43] The source of this example is Wheeler (1979: 312). Hualde (1992: 394) gives *buf estrany* [búv əstɾáɲ] 'strange blow'. Unlike my other sources, however, Recasens (1991: 196) claims that word-final [f] does not undergo voicing in prevocalic position: "A diferència del que s'esdevé amb la resta de consonants fricatives, /f/ i /v/ finals de mot solen realitzar-se [f] davant de mot iniciat en vocal a tot el domini lingüístic (*buf enorme*)" [In contrast with developments affecting the rest of fricative consonants, word-final /f/ and /v/ are usually realized as [f] before words beginning with a vowel throughout the entire domain of Catalan (*buf enorme*) — translation mine]. Recasens (1991: 197) speculates that this exceptional behaviour on the part of the labiodentals cannot be a matter of phonetic implementation, for one expects difficulties in maintaining vocal fold vibration to be first experienced in posterior rather than anterior consonants.

[44] In this respect, the affricate sounds [ts] and [tʃ] behave postlexically just like stop+fricative coda-onset clusters (Wheeler 1979: 310).

not being subject to LICENSE[Lar], would qualify for that rôle.[45] However, this account cannot be correct: if [ʒ] is forced to share the laryngeal node of the following vowel in [mə.te.ʒɔ.mə], there is no reason not to expect spreading in *[mə.teʒ]. All in all, the postlexical behaviour of Catalan fricatives is entirely determined by the right-hand side context.

Let us therefore pursue the idea that the voicing of onset fricatives involves a process of specifically leftward spreading. This can be interpreted as suggesting that Catalan displays a preference for voicing to be initiated as early as possible in the syllable, provided that it does not overlap with a complete closure of the oral cavity in the onset. Formally, we can capture this idea by means of the following constraint:

(3.63) ***CONTVOILAG**

$$* \, [_{[+\text{cont}]} \cdots [_{[+\text{voice}]}$$

Let *v* designate the span of a [+voice] autosegment.
Let *c* designate the span of a [+continuant] autosegment.
If *v* and *c* overlap, then the left edge of *v* must not lag behind the left edge of *c*.

The operation of *CONTVOILAG is simple. Assume that the OCP causes identical adjacent autosegments to merge. If so, any fricative+vowel sequence will be spanned by a single [+continuant] feature. Additionally, the vowel will of course be [+voice]. In such circumstances, *CONTVOILAG will force [+voice] to spread from the vowel to the preceding fricative in order that the onset of voicing shall not lag behind the onset of continuancy:

(3.64)

[mə.te.ʒɔ.mə]	*[mə.te.ʃɔ.mə]
$[_{[+\text{cont}]}$	$[_{[+\text{cont}]}$
. . . $[_\sigma$ ʒ ɔ . . .	. . . $[_\sigma$ ʃ ɔ . . .
$[_{[+\text{voi}]}$	$[_{[+\text{voi}]}$
✓ *CONTVOILAG	✗ *CONTVOILAG

Observe that *CONTVOILAG forbids [+voice] to lag behind [+continuant] but permits [+continuant] to lag behind [+voice]. This possibility is instantiated in (3.65), where voicing has spread from the vowel [ə] to the word-final onset fricative [z], and thence to the preceding coda stop; as a result, [+voice] leads with respect to [+continuant].

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45 Since Catalan sonorants behave as assimilation triggers on a par with obstruents, it is relatively unsurprising that vowels should also bear a laryngeal node capable of being shared with an adjacent fricative. From a crosslinguistic viewpoint, the ability of vowels to support a laryngeal node is beyond doubt, as vowels occur in a range of distinctive phonation types, including voiced, voiceless, breathy and creaky (see e.g. Ladefoged & Maddieson 1996: 315-320).

(3.65) *pocs amics* [pɔg.zə.miks] 'few friends'

$$\begin{array}{l} \qquad\qquad [_{[+\text{cont}]} \\ \ldots\ g_{\sigma}]\,[_{\sigma}\ z\ ə\ \ldots \\ \qquad [_{[+\text{voi}]} \end{array}$$

✓ *ContVoiLag

In this sense, although *ContVoiLag monitors the relative alignment of two featural spans, it cannot be adequately formulated in terms of McCarthy & Prince's (1993b) Align formula. The Align schema requires that the designated edges of two categories should coincide exactly, and, in the event of a misalignment, it does not distinguish between leading and lagging.

It is important to note that the predictions of *ContVoiLag find empirical corroboration outside Catalan. In the West Germanic family, for example, spontaneous fricative voicing is well attested in prevocalic position. Thus, in Middle English dialects south of the Thames, specially Kentish, word-initial [f], [s], and probably [θ], underwent voicing to [v, z, ð]: e.g. Old English *fæder* > Middle English *vader*, Old Kentish *senn* (West Saxon *synn*) > Middle Kentish *zenne* 'sin' (Mossé 1952: §44.1).

At this point, *ContVoiLag appears to have opened a promising line of attack, but there remain some important issues to be dealt with before the analysis can be considered complete. First, we have assumed that *ContVoiLag can force a [+voice] autosegment to spread from a vowel onto an obstruent. Curiously, License[Lar] is unable to produce this effect. Obstruents in absolute final position do not assimilate to a preceding vowel; they remain voiceless even though, being in the coda, they should not support a laryngeal node. There must accordingly exist a violable constraint which prevents vowels and obstruents from sharing laryngeal features. Indeed, Itô, Mester & Padgett (1995) independently postulate such a constraint in their analysis of *rendaku* and voice dissimilation (Lyman's Law) in Yamato Japanese:

(3.66) **No-VC-Link** (Itô, Mester & Padgett 1995: 600)

A laryngeal node must not be simultaneously dominated by a vowel and an obstruent.

According to Itô, Mester & Padgett (1995: §5.3), No-VC-Link is the highest-ranked member of a family of harmonically ordered NoLink constraints which penalize the sharing of voice specifications between dissimilar segments. In Catalan, No-VC-Link is outranked by *ContVoiLag but dominates License[Lar].

*ContVoiLag poses a second problem. To induce voicing in onset fricatives, *ContVoiLag must dominate OnsIdent[Lar]. Yet postlexical voicing does not affect all onset fricatives; only those in prefix-final or word-final position are affected.

(3.67) /GoS/ 'dog'

gos	[gos]	'dog' masc.
gossa	[go.sə]	'dog' fem.
gos alat	[go.zə.lat]	'winged dog'

/𝔹u𝔽/ ‘puff’

buf	[buf]	‘puff’
bufar	[bu.fa]	‘to puff’
buf enorme	[bu.və.nor.mə]	‘enormous puff’

Clearly, the process only targets fricatives which are rhymal at the word level; those already found in onset position in the input to the postlexical module fail to undergo voicing.

(3.68)	*gossa*	*gos alat*
Underlying representation	/𝔾o𝕊ə/	/𝔾o𝕊 əla𝔻/
Word level	.go.sə.	.gos. .ə.lat.
Postlexical level		
Voicing	—	.go.zə.lat.
	‘dog’ fem.	‘winged dog’

Here I shall briefly explore two possible solutions to this problem. One is to postulate a class of faithfulness constraints relativized to the prosodic status of the target segment in the input representation. An alternative answer would involve reanalysing word-level voice neutralization in the coda as involving delaryngealization (i.e. loss of the laryngeal node) rather than devoicing; missing voice specifications would then be supplied postlexically by assimilation, with default devoicing in the absence of an assimilation trigger. Although both solutions work, the second one is theoretically more parsimonious, and I shall therefore assume that it is the correct one.

Let us consider the first solution. Whilst *CONTVOILAG must outrank ONSIDENT[Lar] in the postlexical hierarchy, it will not overgenerate if it is itself dominated by the following constraint:

(3.69) **ONS(i)IDENT[Lar]**

Let *a* be a segment in the input.
Let *b* be a correspondent of *a* in the output.
Let *a* be in onset position.
The laryngeal specifications of *b* are identical with those of *a*.

The only difference between ONSIDENT[Lar] and ONS(i)IDENT[Lar] lies in the fact that, whereas the former is relativized to the prosodic position of the target segment in the output, the latter refers to input syllabification. To date, positional faithfulness constraints like ONS(i)IDENT[Lar] have scarcely figured in the literature, but this is hardly surprising. Most OT research has so far been conducted within a strictly parallelist framework, where the phonological content of morphemes in the input to EVAL is directly drawn from the lexicon. Since lexical representations are subject to Richness of the Base, they may not be specified with predictable prosodic structure. Accordingly, strictly parallelist models countenance no input prosodification for positional faithfulness constraints to refer to. In interleaved OT, however, the situation is quite different, for, as has been abundantly illustrated above, the input to noninitial strata is nonrich: it contains prosodic structure generated in its pass through higher grammatical levels. Thus, not surprisingly, ONS(i)IDENT finds precedents in Kiparsky's work on Lexical Phonology and Morphology in OT. In his analysis of Arabic syllabification, for example, Kiparsky (1998) motivates a constraint MAX-V́ which demands that a vowel should not be deleted if it bears stress in the input; crucially, it is irrelevant whether its output correspondent is stressed or unstressed.

Note, however, that ONS(i)IDENT[Lar] touches on important matters of principle: by referring to the prosodic structure of the input, do such positional faithfulness constraints violate the fundamental OT tenet of 'Output Orientation'? I shall answer this question in the negative. The import of Output Orientation can be perspicuously defined in terms of another fundamental optimality-theoretic tenet: that of 'Economy' or 'Minimal Violation' (Prince & Smolensky 1993: 27).

(3.70) **Output Orientation**

The violation of input-output faithfulness constraints is minimal, subject only to the satisfaction of higher-ranked markedness constraints on output representations.

According to (3.70), phonological processes involving unfaithfulness cannot be triggered by conditions defined upon input representations: unfaithful correspondence is tolerated only if required to increase the structural harmony of outputs. In this sense, Output Orientation establishes a clear demarcation between OT and phonological models such as SPE or Lakoff's Cognitive Phonology (Lakoff 1993). The familiar rewrite rules of SPE alter representations in response to the presence of particular configurations in their input, and their application is not reversed if some other rule removes the conditioning environment from the output; it is this feature that renders them singularly apt at describing opaque phenomena of the overapplication type. In Cognitive Phonology, mappings are defined by means of 'constructions' relating adjacent levels of grammatical representation; crucially, when a construction is solely activated by structure present at the higher (more abstract) level, it is notationally equivalent to an SPE rule:

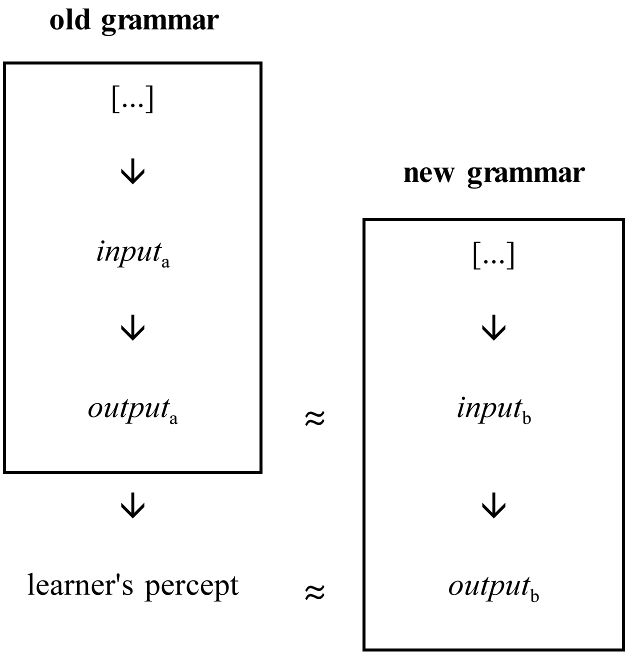
(3.71) **SPE and Cognitive Phonology violate Output Orientation**

SPE	*Cognitive Phonology*	
a –> b / c__d	Level A:	c a d
		|
	Level B:	b

Output Orientation thus proves to be a cornerstone of OT; any relaxation of this principle would compromise the identity of the theory. That said, it should be clear that Output Orientation is not violated by relativizing positional faithfulness constraints to input prosodic structure. ONS(i)IDENT[Lar], for example, does not have the power to induce input-output disparity: like ordinary faithfulness constraints, it simply moderates the effects of markedness constraints on output representations (in the case at hand, it interacts with *CONTVOILAG).[46]

Furthermore, one can argue that positional faithfulness constraints relativized to input prosodification are directly grounded on the operation of reanalysis in the course of language acquisition. As is well known, phonological innovations often arise through processes of misanalysis whereby the hearer misinterprets some phonetic disturbance of the speech signal as realizing some feature of the output representation intended by the speaker (Ohala 1989, 1992, 1993). This often leads learners to construct grammars where the old output representation appears as the input to an innovative phonological mapping:

(3.72)



This, in essence, is the familiar notion of ‘rule addition’. Observe, however, that the prosodic structure of *output*$_a$ directly determines the probability that a segment will be subject to distorted perception by the learner. Since the mapping *input*$_b$—>*output*$_b$ is homologous with that between *output*$_a$ and the learner's distorted percept, the prosodic structure of *input*$_b$ is likely to play a governing rôle in the innovative mapping.

I conclude that constraints of the ONS(i)IDENT format, where faithfulness is relativized to the position of the target in the prosodic structure of the input, could be provided with a solid theoretical foundation. At this point, therefore, we could provide a revision of hierarchy (3.60) which accounts for the postlexical behaviour of fricatives as illustrated in (3.62) and (3.67). As I have been assuming throughout, OBS—>LAR is in superordinate position; it is included here for the sake of completeness.

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[46] The ‘disparate correspondence constraints’ postulated by Archangeli & Suzuki (1997) provide a useful term of comparison. These constraints do violate Output Orientation, for they require that an output segment should bear a certain property if its input correspondent meets a designated condition. In this sense, they work as ‘antifaithfulness constraints’, much like the devices illustrated in (3.71). For more general discussion, see Kager (1999: §9.2.2).

(3.73) **Postlexical voice neutralization**

```
      Ons(i)Ident[Lar]
            |
       *ContVoiLag
            |      \
            |       No-VC-Link  Obs—>Lar
            |            |       /
      OnsIdent[Lar]  License[Lar]
                 \   /         \
                  VOP           Ident[Lar]
```

Nonetheless, postulating a constraint such as Ons(i)Ident[Lar] is theoretically costly, even if it is not incoherent. An alternative that relied on resources already available would therefore be preferable. Fortunately, such an alternative exists. To establish this point, let us reconsider the arguments for our claim that voice oppositions are neutralized in the coda at the word level. The key piece of evidence for this proposal lies in the fact that the voice specifications of prevocalic word-final obstruents are entirely predictable: stops are voiceless and fricatives are voiced. Since onset obstruents are not subject to voice neutralization elsewhere, one must conclude that word-final consonants undergo neutralization at the word level, for at that stage they are syllabified in coda position. The question now arises as to the exact nature of this word-level process of voice neutralization. We observe that the voicing of prevocalic word-final fricatives can be explained through assimilation, whereas the voicelessness of prevocalic word-final stops cannot. This would suggest that the word-level process of voice neutralization involves obstruent devoicing, as we have been assuming so far. This conclusion is, however, not necessary, for the voicelessness of word-final stops reflects the unmarked laryngeal setting for obstruents in general. Accordingly, it is equally possible to assume that, at the word level, obstruents do not devoice, but rather become laryngeally unspecified. This state of affairs will obtain if, at the word level, License[Lar] is promoted over Obs—>Lar and forces laryngeal nodes to be delinked from coda consonants.[47]

Pursuing this line of enquiry, postlexical voice assimilation can be interpreted as providing unspecified segments with laryngeal features; in those environments where there is no suitable spreading trigger, devoicing will apply by default. The processes restoring full specification can be set in motion by promoting Obs—>Lar back to superordinate position. Crucially, the only onset fricatives vulnerable to assimilation will be those in prefix-final or word-final position, for only they emerge from the word level lacking a laryngeal node. Accordingly, the correct results will be obtained if OnsIdent[Lar] outranks *ContVoiLag, but is in turn dominated by Obs—>Lar; as anticipated, Ons(i)Ident[Lar] is not required.

[47] Recall, however, that spreading of a laryngeal node from a following onset consonant does not violate License[Lar]. To guarantee that missing voice specifications are not supplied by spreading, one would therefore have to assume that Obs—>Lar is also dominated by the appropriate NoLink constraints; see (3.74a).

(3.74) **Catalan voice neutralization with word-level delaryngealization**

(a) *Word level: delaryngealization*

No-VC-Link License[Lar] OnsIdent[Lar]
\ / \ |
Obs—>Lar Ident[Lar] VOP

(b) *Postlexical level: assimilation + default devoicing*

Obs—>Lar
/ \
OnsIdent[Lar] Ident[Lar]
|
*ContVoiLag
|
No-VC-Link
|
License[Lar]
|
VOP

Ironically, we have come full circle in our analysis of Catalan voice neutralization. The approach outlined in (3.74) matches very closely the classical rule-based autosegmental account propounded in Mascaró (1987): in the first step, coda obstruents lose their laryngeal nodes; full laryngeal specification is subsequently restored by assimilation and default devoicing, which apply in complementary sets of environments. Interestingly, (3.74) is fully compatible with our treatment of the absence of spirantization in codas: if, as established in §x.x.x, spirantization only targets stops which are voiced in the input to the postlexical module, then word-level coda delaryngealization will have the same bleeding effect as word-level coda devoicing. In fact, I am not aware of any empirical evidence from within Catalan which can help us to discriminate between these two alternatives. The choice must accordingly be made on theoretical and crosslinguistic grounds. Possible criteria include the following:

- The devoicing analysis resorts to a positional faithfulness constraint relativized to input prosodification, viz. Ons(i)Ident[Lar]. If good arguments are found to reject such constraints, delaryngealization will prove preferable.
- The delaryngealization account crucially assumes that the output of the word level contains rhymal obstruents lacking specifications for voice. From a typological viewpoint, therefore, laryngeal underspecification is predicted to be a possible surface pattern for obstruents, at least in the coda.[48] If this prediction fails to receive crosslinguistic corroboration, then the devoicing analysis should be favoured.

To date, no independent argument has been made for positional faithfulness constraints relativized to input prosodification. This is not necessarily significant since, as I pointed out above, scholars have not bee lookng for such arguments. Nonetheless, constraint proliferation

[48] The concept of surface underspecification is explicated by Keating (1988) and Cohn (1990). Cohn's study refers to the feature [±nasal].

is intrisically undesirable. We do however have empirical arguments for surface underspecification of obstruent voicing: see Hsu (1996) uses Taiwanese data to show that neutralized obstruents are phonetically targetless and become voiced or voiceless through phonetic interpolation; see Steriade (1997: 22). I therefore conclude that the delaryngealization analysis is the correct one.

3.6. Voice neutralization and spirantization: ordering relations in interleaved OT

Our inquiry into Catalan voicing and continuancy was prompted by the perplexing observation that voiced stops fail to undergo spirantization in the rhyme (§x.x.x). In this respect, Catalan violates well-founded phonotactic expectations and departs from the pattern prevalent in the Iberian Peninsula. We have now gathered all the pieces of this puzzle: in section x.x.x, particularly (3.8), we set up a working model of spirantization; sections x.x.x to x.x.x have in turn provided an exhaustive analysis of voice neutralization. It just remains to fit these pieces together.

The solution to our problem relies upon two crucial ordering effects: spirantization is bled by delaryngealization but counterfed by assimilation (§x.x.x). Consider the following example:

(3.75)		*llop gelós*	
Underlying representation		/ʎo𝔹 ʒəloz/	
Stem level		.ʎob. .ʒə.loz.	
Word level	Delaryngealization	.ʎo**P**. .ʒə.los.	} Bleeding
Postlexical level	Spirantization	—	
	Assimilation	.ʎo**b**.ʒə.los.	} Counterfeeding
		'free wolf'	

Our task is to model these interactions in an interleaved constraint-based grammar, which places far tighter restrictions on opacity than Harris's rule-based framework. Recall that, in our theory, opacity can arise through the interaction between levels, but there can be no serial effects within cycles, where mappings are effected in the strictly parallel fashion characteristic of OT.

The bleeding interaction between delaryngealization and spirantization poses no particular difficulty. Delaryngealization must be word-level because it overapplies to prevocalic word-final stops resyllabified into the onset. Spirantization must in turn be postlexical because it applies normally across word boundaries. Accordingly, delaryngealization must precede, and therefore bleed, spirantization. In this sense, interleaved OT correctly predicts the relative ordering of these two processes on the basis of independent evidence from their domain of application. In contrast, Harris (1993) assigned devoicing to the postlexical stratum and was therefore compelled to stipulate the extrinsic ordering devoicing > resyllabification > spirantization > assimilation; see (3.28). As I argued in section x.x.x, however, Harris's ascription of devoicing to the postlexical module stems from the erroneous assumption that the phonology of clitic groups cannot be computed at the word level because cliticization is effected in the syntax.

At first blush, the interaction between spirantization and assimilation appears less straightforward. Like spirantization, voice assimilation can only be postlexical, for it applies normally across word boundaries. Therefore, interleaved OT demands that both processes apply in parallel. Yet assimilation does appear to counterbleed spirantization: those stops which become voiced through assimilation fail to spirantize; as I have repeatedly stated, spirantization only applies if its target is voiced in the input to the postlexical module. The key to this problem lies in the observation that spirantization and assimilation operate like consecutive links in a synchronic chain shift:[49] assimilation maps input [P] onto [b], and spirantization converts [b] into [β], but taking [P] to [β] in one fell swoop is prohibited.

(3.76) **Interaction of assimilation and spirantization**

(a)	✓	[P] —> [b]	*IDENT[Lar]	*Assimilation*
(b)	✓	[b] —> [β]	*IDENT[cont]	*Spirantization*
(c)	✗	[P]---------> *[β]	*IDENT[Lar], *IDENT[cont]	*Fell swoop*

This suggests that the postlexical phonology of Catalan imposes a maximum limit on the featural distance between input and output correspondents: a mapping can be unfaithful in respect of either voice or continuancy, but not both features simultaneously.

Kirchner (1995, 1996) has shown that this type of 'distantial faithfulness' effect need not be implemented serially, but can arise from the local conjunction of constraints in a strictly parallel derivation. In the case at hand, the fell-swoop mapping will be blocked by the macroconstraint IDENT[Lar]&IDENT[cont] taking individual segments as its local domain. The desired effect is obtained by ranking IDENT[Lar]&IDENT[cont] above VSP in hierarchy (3.8). The effects of this hierarchy are illustrated in tableau (3.77).

In the mapping [ʎo.**b**ə]—>[ʎo.**β**ə], spirantization is possible because the target is already voiced in the input; accordingly, there is unfaithfulness in respect of continuancy but not in respect of voice, and IDENT[Lar]&IDENT[cont] is not violated. In the case of [ʎo**P**.ʒe.los]—>[ʎo**b**.ʒe.los], in contrast, OBS—>LAR and LICENSE[Lar] demand assimilatory voicing, whilst VSP puts pressure on the resulting voiced stop to spirantize. The parse *[ʎo**β**.ʒe.los] would satisfy LICENSE[Lar] and VSP simultaneously, but it fatally violates

[49] The term 'chain shift' is used here for purely illustrative purposes: there is of course no implication that the interaction between assimilation and spirantization in Catalan tends to preserve phonemic distinctions; it patently does not. No association is therefore intended with the functionalist connotations which the terms 'chain' and 'shift' acquire in the work of Luick (1896, 1914-1940) or Martinet (1952, 1955). Similarly, I do not suscribe to neofunctionalist theories incorporating antimerger constraints, such as Fleming's (1995) Dispersion Theory of Contrasts.

superordinate IDENT[Lar]&IDENT[cont];[50] assimilatory voicing and spirantization are thus incompatible. Since LICENSE[Lar] dominates VSP, assimilation prevails.

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[50] I assume that IDENT[Lar] is violated when input [0voice] is mapped onto output [+voice] or, alternatively, when an input segment lacking a laryngeal node is mapped onto an output segment with a laryngeal node dominating the element [voice].

Mascaró & Wetzels (2000: ???) propose a different interpretation of voice faithfulness:

> We assume that in a binary voice theory only contradictory (*<[αvoice] —> [-αvoice]>) specifications on corresponding input/output segments will be marked as violations of the IDENTVOICE constraint [...].

This proposal departs from the standard IDENT schema as defined by McCarthy & Prince (1995):

> IDENT(F)
> Correspondent segments have identical values for the feature F.
> If x*R*y and x is [αF], then y is [αF].

It is clear that in this statement [αF] ranges over any possible value of [F], including [+F], [-F] and [0F]. Moreover, Mascaró & Wetzels's suggestion makes sense in a phonological framework where underspecification characterizes lexical representations (Lexical Minimality) but surface forms are fully specified (Full Specification); see Steriade (1995: 114). However, these assumptions are inimical to the spirit of OT, where underlying representations are subject to Richness of the Base, and underspecification (whether in input or output forms) is treated as emerging from the ranking of constraints in the grammar (Itô, Mester & Padgett 1995).

(3.77) *lloba* [ʎo.**β**ə] 'she-wolf'
llop gelós [ʎo**b**.ʒə.los] 'jealous wolf'

Postlexical level		ID[Lar]&ID[cont]	ONSID[Lar]	LIC[Lar]	VSP	ID[Lar]	ID[cont]	VFP
.ʎo.**b**ə.	.ʎo.**ɸ**ə.	*!	*!			*	*	
	.ʎo.**p**ə.		*!			*		
	.ʎo.**b**ə.				*!			
	.ʎo.**β**ə. ☜						*	*
.ʎo**P**. .ʒə.los.	.ʎo**ɸ**.ʒə.los.	*!		*!		*	*	
	.ʎo**p**.ʒə.los.			*!		*		
	.ʎo**ɸ**.ʃə.los.	*!	*!			*	*	
	.ʎo**p**.ʃə.los.		*!			*		
	.ʎo**β**.ʒə.los.	*!				*	*	*
	.ʎo**b**.ʒə.los. ☜				*	*		

Finally, it should be acknowledged that the issue of local conjunction is currently surrounded by a lively controversy; no agreement has been reached on the requirements that a pair of constraints must meet to be deemed conjoinable. Nonetheless, a macroconstraint such as IDENT[Lar]&IDENT[cont] has impeccable credentials:

- According to the 'unique focus' condition of Crowhurst & Hewitt (1997), both members of a conjunction must share the same primary argument. Crowhurst & Hewitt (1997: 10) define the primary argument of a constraint as that linguistic object "upon which some condition of maximum harmony is predicated"; primary arguments, they point out, are "always interpreted with universal scope." Following this definition, the primary argument of both IDENT[Lar] and IDENT[cont] consists of any pair of segments *a* and *b* where *a* is in correspondence with *b*. Therefore, IDENT[Lar]&IDENT[cont] fulfils the unique focus condition.
- McCarthy (1998: §4.3) implies that the local domain of a conjunction must have 'formal status': i.e., presumably, it must coincide with some recognized unit of phonological structure. The local domain of IDENT[Lar]&IDENT[cont] is the segment.
- Łubowicz (1998) defines the domain of a local conjunction as the smallest span within which both of its members can be evaluated. Since both IDENT[Lar] and IDENT[cont] are assessed over segments, our assumption that IDENT[Lar]&IDENT[cont] targets individual segments complies with Łubowicz's definition.
- Itô & Mester (1998: §2.2) argue that faithfulness constraints may not be locally conjoined with markedness constraints.[51] Even more stringently, Miglio & Fukazawa (1997) suggest that conjuncts must belong to the same family. IDENT[Lar]&IDENT[cont] clearly satisfies both requirements.

This concludes my analysis of voicing and continuancy in Catalan obstruents. In the course of a somewhat protracted discussion, we have uncovered a wealth of intricate interconnections between various aspects of Catalan phonology; these include the inventory of distinctive underlying segments, the operation of spirantization and voice neutralization, the pattern of syllabification and resyllabification, and the hierarchy of phonological domains defined by the grammatical structures of the language. Interleaved OT has proved equal to this empirical challenge, suggesting that the resources of interleaving suffice to account for the opacity effects found in the phonology of natural languages. Notably, we have been able to dispense with Harris's battery of four extrinsically ordered postlexical rules (devoicing > resyllabification > spirantization > assimilation). In sum, the facts of Catalan corroborate the key principle of interleaved OT: grammatical constituency defines intrinsic precedence relationships between phonological cycles; beyond this, phonological theory has no need of serial derivations.

The following sections deal with the implications of our Catalan data for strictly parallel implementations of OT. These turn out to be devastating. In §x.x.x I argue that Catalan provides unequivocal evidence against McCarthy's (1999, to appear) dismissal of nonvacuous Duke-of-York gambits; it is shown that the crucial intermediate stage in such derivations need not coincide with an independent surface form. Moreover, the Catalan case suggests that, from the viewpoint of learnability, Duke-of-York manoeuvres do not constitute a homogeneous class: I will demonstrate that, with fairly trivial resources, the learner can easily detect the bleeding effect of word-level devoicing upon postlexical spirantization. Thus,

[51] They have since withdrawn this claim; see Itô & Mester (1999) and Baković (1999, 2000).

the vaunted superiority of Sympathy Theory over interleaved OT proves illusory. In section x.x.x I will consider a number of attempts at dealing with the Catalan Duke-of-York gambit in Sympathy Theory. All of them will be shown to flounder upon a major technical obstacle, which I will describe as a Richness of the Base paradox: since underlying /𝔹/ is rich in continuancy and stridency specifications, input-output faithfulness cannot explain the fact that the devoiced realization of /𝔹/ is [p] rather than [f], nor that spirantization of /𝔹/ yields [β] rather than [v].

Note added on 26 May 2002

The argument referred to in the final paragraph is developed in:

Bermúdez-Otero, Ricardo (2002). "Cyclicity or sympathy? A case study." Handout of paper presented at the 10th Manchester Phonology Meeting, Manchester, 25 May 2002.

Note added on 16 March 2006

The handout referred to in the previous note is now available online at www.bermudez-otero.com/10mfm.pdf