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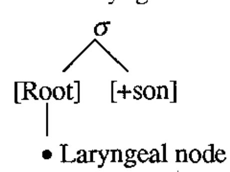
POSITIONAL FAITHFULNESS AND VOICING ASSIMILATION IN OPTIMALITY THEORY*

This paper proposes a set of constraints within the framework of Optimality Theory that accounts for syllable-final laryngeal neutralization and voicing assimilation in obstruent clusters. The interaction of positional faithfulness and markedness is shown to result in laryngeal neutralization. Regressive assimilation is shown to be a result of the interaction of positional faithfulness with a constraint preferring adjacent obstruents to agree in voicing. Rerankings of the proposed constraints account for attested patterns of voicing assimilation and neutralization: unlike previous neutralization and spread analyses, this approach makes the correct prediction that it is equally natural for voicing assimilation in clusters to combine with either devoicing of or retention of voicing distinctions in word-final consonants. It is argued that the interactions of these constraints account for why voicing assimilation is always regressive unless special circumstances hold.

1. Introduction

Much work in autosegmental phonology, although assuming a derivational theory relying heavily on phonological rules, recognizes that wellformedness constraints are crucial to constructing explanatory analyses. For example, many languages restrict laryngeally marked segments from appearing syllable-finally; a familiar example is German, which devoices obstruents in this position. Lombardi (1991, 1995a) argues that such laryngeal neutralization is the result of a licensing constraint active in some languages which allows laryngeal features only in the following configuration:

(1) The Laryngeal Constraint



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The relevant position is before [+son] to include both vowels and sonorant consonants, since distinctions are maintained in onset clusters like /tr, dr/ in the relevant languages.

The constraint-based analysis is argued to have several advantages over a solely rule-based one. One is specific to laryngeal phonology, regarding the impossibility of stating the proper environment for a neutralization rule, but others are more general. For example, there are languages that do not show active devoicing alternations because no underlying forms have final voiced obstruents; a rule is unsuitable to analyzing such cases. But we do want to account for the fact that such languages have the same distribution as German, with voiced obstruents allowed initially but not finally, and the constraint is true of both types. Another goal of the constraint-based analysis was a better account of typology. If any rule affecting Lar that can be constructed with the available rule-writing devices is permitted, the grammar overgenerates. Proposing instead that UG provides the constraint in (1), and that languages choose to obey it or not, narrows down the possibilities.

Such an analysis that incorporates constraints into a derivational theory must also account for how the rules and constraints interact. Lombardi (1991, 1995a), following a suggestion of Mester and Ito (1989), argues that delinking is the default repair strategy, since it introduces no new information. This gives the correct result that laryngeal distinctions are lost in unlicensed positions and, combined with autosegmental spreading, accounts for the following typology:

(2)a. Syllable-final neutralization
German

b. Voice unrestricted
English level II, Georgian, Coeur d'Alene
Kannada, Tulu (Cho 1990)

c. No voicing in obstruents
Maori, Ainu, etc.: see Maddieson (1984)

d. Voicing assimilation in obstruent clusters with word-final neutralization
Polish, Dutch, Catalan, Sanskrit

The addition of a word-edge licensing constraint is argued to account for a final type of language:

e. Voicing assimilation in obstruent clusters with word-final voicing contrast
   Yiddish, Romanian, Serbo-Croatian

Other logically possible patterns do not occur: for example, languages which preserve voicing in coda but not in onset, or languages which devoice word-final but not word-internal syllable-final consonants.

The interaction of rules and constraints in the Laryngeal Constraint analysis works because it happens that violations of this constraint are always resolved by neutralization. However, in many other cases in segmental phonology the interaction of rules and constraints is not so simple. Ito's (1986) Coda Condition, which restricts Place syllable-finally, is enforced by a variety of rules both across languages and within the same language: epenthesis, deletion, and assimilation can all be used to yield Coda Condition-obeying surface structures. But none of these rules are formally connected to the constraint itself. This is an example of the well-known 'conspiracy' problem of Kisseberth (1970). This more general problem is concealed by the neat nature of the laryngeal facts, so that while the Laryngeal Constraint analysis is largely successful for the particular data, the flaw is that it cannot be extended to other rather similar cases in segmental phonology.

In response to the problems faced by grammars that attempt to combine rules and contraints, Optimality Theory (Prince and Smolensky 1993, McCarthy and Prince 1993) proposed that grammars consist of constraints alone. However, this founding work in Optimality Theory concentrated mainly on prosodic aspects of phonology, such as syllable structure and prosodic morphology. Given the previous work on constraints in autosegmental phonology, it seemed clear that Optimality Theory could be extended to cover segmental alternations, but the details remained to be worked out.

More recently there has been some attention paid to how to analyze segmental alternations in OT, and this paper falls into that category. I will propose an OT analysis of the laryngeal neutralization and assimilation typology. I will show that these alternations can be seen, in the standard OT manner, to be the result of conflicts between faithfulness and markedness; these conflicts are resolved differently in languages due to different constraint rankings. The position of licensing in Lombardi's (1991, 1995a) constraint will be shown in this analysis to be a position of special faithfulness to underlying laryngeal distinctions. This analysis will thus fit in with recent work that shows that positional faithfulness constraints are important to analyzing the distribution of segmental contrasts in OT (Beckman 1995, 1996; Selkirk 1995; Padgett 1995).

A few more specific contributions will also be made. First, no special licensing is needed for the cases in (2e); they will be seen to fall out from rerankings of the basic constraints, which is appropriate since they are an equally common and natural type of grammar. Second, an additional type of grammar is predicted, which I will argue is seen in Swedish; thus this account results in superior typological coverage. Finally, I will argue that the crosslinguistic restrictions on direction of assimilation – that it is normally regressive – are better handled by this approach.

2. The Constraints and Interactions in Outline

2.1. *Faithfulness Constraints*

I will employ the following two faithfulness constraints for laryngeal features in this analysis:

(3) IDentOnset(Laryngeal) (abbreviated IDOnsLar):
Consonants in the position stated in the Laryngeal Constraint (1) should be faithful to underlying laryngeal specification

(4) IDent(Laryngeal) (IDLar)
Consonants should be faithful to underlying laryngeal specification

These constraints belong to the Ident(F) family of Correspondence constraints proposed by McCarthy and Prince (1995). Ident(F) constraints check that input and output *segments* agree in featural specification. I will assume privative [voice](see Lombardi 1995c for an argument within OT that [voice] must be privative). Although the main definition of Ident in McCarthy and Prince (1995) assumes binary features, there is also discussion of its application with privative features (see section 3.8, p. 71), and the assessment of violations is straightforward: two consonants without Laryngeal features are identical in Laryngeal specification; two consonants marked [voice] are likewise identical; in contrast, a consonant without Laryngeal features and one marked [voice] differ in laryngeal specification, and so incur a violation of the Ident constraint.

One of the proposed Ident constraints, IDOnsetLar, is relativized to position, 'Onset' obviously being used only as a shorthand for the Laryngeal Constraint position. Such constraints are suggested by Selkirk (1995) and Beckman (1995, 1996) as a way of accounting for the observation (which goes back at least as far as Trubetskoi 1939; see also, for example, Goldsmith 1989, 1990, Steriade 1995) that languages may maintain a distinction only in prominent positions and neutralize it elsewhere. The 'prominent' position differs for different features (see Beckman 1996 for a number of different types of examples); as shown by Lombardi (1991, 1995a), the position in (1) is the important one in the case of Laryngeal distinctions. This position has also been shown to be important for laryngeal features in work by Kingston (1985, 1990) and Steriade (1993, 1995), and is also relevant for other consonant features; see Padgett (1995) on Place assimilation; and cf. the work of Ito (1986) on Place restrictions in coda as well as Goldsmith (1989, 1990) on onset/coda asymmetries.

2.2. *Markedness*

Following Prince and Smolensky (1993), I assume a family of markedness constraints on feature specifications, of which *LAR is a member.

(5) *LAR: do not have Laryngeal features

This constraint will be interpreted to give one mark for each voiced obstruent; that is, an assimilated cluster incurs two violations of *LAR. The evidence for this will be presented in section 3.1.

I assume that [voice] is a privative feature, following Lombardi (1991, 1995b) and references therein; see also arguments in Lombardi (1995c) that this assumption is required to explain certain asymmetries in the phonology of Place and Voice.[1] The assumption of privative features is also crucial to the interpretation of this constraint: A voiced consonant will receive one mark for *LAR, and a voiceless one no marks, as it bears no laryngeal feature.[2]

[1] However, see Inkelas, Orgun, and Zoll (1994) where an argument for ternary voice specification is presented, in an OT context, to solve a problem in Turkish phonology. See also footnote 10 for additional comments on this case.

[2] A question that I will leave open about this constraint is whether it applies to sonorants. In fact, it is not marked for a sonorant to be voiced; rather it is the normal situation. This could be handled by having *LAR defined as "Obstruents should not have Laryngeal features." However, the more general form of the constraint would allow us to extend it to neutralization of other Laryngeal features: not only do these tend also to neutralize in the same position, but both sonorants and obstruents are affected (see Lombardi 1991, 1995a, b). It could be the case that *LAR is violated by voiced sonorants, but that they must nevertheless retain [voice] in most situations due to a dominant constraint demanding sonorant voicing. Also, given that only one laryngeal feature is at issue in the examples in this paper, we cannot distinguish whether violations are counted on the Laryngeal node (if any) or individual features. See Lombardi (to appear) for discussion of both issues. For simplicity I omit *LAR marks for sonorants.

I also assume a constraint that enforces voicing assimilation in obstruent clusters:

(6) AGREE: Obstruent clusters should agree in voicing

As stated, AGREE applies only to obstruent clusters and thus will only be able to trigger assimilation of obstruent voicing.

As stated, sonorants are unaffected by this constraint by definition. This may actually be a result of a constraint interaction effect; I return to this in section 5. However, the restriction to clusters appears to be fundamental. Voicing assimilation never crosses vowels, unlike other kinds of assimilation (vowel harmonies, for example) that show long-distance effects. If the blocking of voice assimilation across vowels were a constraint interaction effect, we would expect to see cross-linguistic variation, with some languages spreading consonant voicing to consonants across vowels and some not, due to constraint reranking. This variation does not occur, so it seems that the impetus to agree in voicing really only applies to the cluster situation. Therefore, this is definitional for the constraint I am proposing: it is only concerned with a string of adjacent consonants.[3]

An important point is that this constraint is not inherently directional: direction of assimilation will be a constraint interaction effect. This will be discussed further in section 3.6.

In the next section the examples will be confined to those without complex onsets or codas, in order to simplify the presentation of the main constraint interactions. Tautosyllabic clusters will then be discussed in section 4.

3. Factorial Typology of Constraints

Note that in this section, to facilitate comparison across different grammar, I will use the same lettering of inputs in examples where possible, as follows:

(7)a. Word-final voiced obstruent

b. Voiced-voiceless obstruent cluster

[3] A reviewer suggests that this impossible type of assimilation could be ruled out by a universally fixed ranking. However, all plausible cases of universal rankings that I know of in the OT literature are rankings within a single constraint family, so that thus far it seems that we should assume that this is the only type of ranking fixed in UG. To block voice spreading across vowels with a fixed ranking would presumably involve relative rankings of constraints from different families – at least the family that triggers the assimilation and the one that required faithfulness to the features involved, if not others as well.

c. Voiceless-voiced obstruent cluster

d. Voiced-voiced obstruent cluster

3.1. *Syllable-final Neutralization*

Syllable-final laryngeal neutralization is a common phenomenon cross-linguistically. A familiar example is standard German. Morphemes may end in voiced obstruents, but such consonants devoice if they surface in the syllable coda. This is seen in the alternations in (8) (Wiese 1996, p. 200):[4,5]

(8) German syllable-final neutralization

Lo[p]	–	Lo[b]es	'praise	–	gen.'
Ra[t]	–	Ra[d]es	'advise	–	gen.'
Sar[k]	–	Sär[g]e	'coffin	–	plu.'
Gra[s]	–	Grä[z]er	'grass	–	plu.'
Re[g]en	–	re[k]nen	'rain	–	to rain'
ja[g]en	–	Ja[k]den	'to hunt	–	hunts'
		Ja[kt]	'hunt'		

The interaction of *LAR with the positional faithfulness constraint can result in voiced obstruents being possible in the onset and not the coda,

[4] There are a number of words with voiced stops in problematic positions, with variable pronunciations for at least some speakers, such as *Han[d]lung-Han[t]lung*. The simplest solution is to assume, along with Wiese (1996, p. 202), that this is due to variability in syllabification: that in Han.[d]lung, the voiced obstruent is not in the coda. (Wiese cites Vennemann 1968 and also gives an argument based on the interaction of devoicing and g-spirantization.) This requires that we recognize some onset clusters word-internally that do not occur word-initially. Other approaches to these examples are surveyed by Brockhaus (1995). Earlier work by Wiese claims that these consonants are ambisyllabic, in which case they could escape devoicing by something like the Linking Condition; this would seem to also nicely account for Brockhaus' observation (p. 76) that speakers do not give consistent judgments regarding which syllable the questionable obstruent belongs to. Finally, see Levy (1997) for an OT account of these forms which invokes output-output correspondence. There are also studies that have claimed to show that laryngeal distinctions are not fully neutralized in languages including German and Polish, but Fourakis and Iverson (1984) show that these effects are due to experimental flaws; their arguments also apply to similar later studies (Slowiaczek and Dinnsen 1985, Charles-Luce 1985).

[5] Consonants that are glottalized or aspirated, including sonorants, are also prohibited syllable-finally in many languages (see Lombardi 1991, 1995a, b for examples). However, these features assimilate far less frequently than voicing, and so their phonology is less useful for testing the possible combination of different alternations and will not be addressed in this paper. I know of no reason to believe that the analysis of neutralization for these features is any different from that proposed herein for voicing; the infrequency of assimilation is likely due to perceptual factors.

as in German. This is the result of the ranking IDOnsLar ≫ *LAR IDLAR. Consider first a simple monosyllable:

(9) Syllable Final Neutralization Ranking (German)

a. /rad/	IDOns	*Lar	IDLar
rad		*!	
☞ rat			*
b. /gut/			
☞ gut		*	
kut	*!		*

As we see in tableau (9), this ranking gives devoicing syllable-finally, but faithfulness in onset position. For an onset consonant, it is more important to obey IDOnsLar (Onsets should be faithful to underlying voicing) than to obey *LAR (Do not be voiced). But for a coda, markedness outranks the only relevant faithfulness constraint, so it will devoice. It is more important to obey *LAR (Do not be voiced) than to obey IDLAR (Be faithful to input voicing).

Next, consider alternations in word-internal syllables. Most of these examples are straightforward given the discussion so far, but (10c) crucially demonstrates the importance of the interpretation of *LAR:

(10) Word Internal Clusters (German)

	IDOns	*Lar	IDLar	
b. /sagte/				'said, 1st person sg.'
sa[gt]e		*!		
☞ sa[kt]e			*	
sa[gd]e	*!	**	*	
c. /ratgeber/				'adviser'
☞ ra[tg]eber		*		
ra[dg]eber		*!*	*	
ra[tk]eber	*!		*	
d. /rundgang/				'stroll'
run[dg]ang		*!*		
☞ run[tg]ang		*	*	
run[tk]ang	*!		**	

As in tableau (9), syllable-final consonants devoice, allowing satisfaction of *LAR at the expense only of lower-ranked IDLAR; but voiced syllable-initial consonants remain voiced, since satisfying IDOnsLar (by retaining underlying voicing) is more important than satisfying *LAR (which assigns a mark to each voiced consonant). So far this is the same as we saw in (9). But now (10c) also shows the importance of the interpretation of the markedness constraints as I have described them, where each voiced *segment* receives a mark. Given the assumption of the richness of the base in OT, we must be able to handle the possible input with a cluster with doubly linked [voice]. If *LAR counted [voice] autosegments instead of voiced segments, such a cluster would get only one mark for *LAR:

(11) Incorrect Interpretation of *LAR

/rundgang/ \/ [voice]	IDOns	Lar	IDLar
a. rundgang		*	
b. runtgang		*	*!
c. runtkang	*!		**

The outcome would be that (a) is optimal, so that voiced clusters would remain so, but syllable-final consonants would devoice in all other environments. The language would thus have voiced-voiced, voiceless-voiceless, and voiceless-voiced clusters, but no voiced-voiceless clusters. There appears to be no such language. Thus, to rule out this possibility and to achieve the result that neutralization is a direct result of markedness, it must be the case that each voiced consonant receives a mark for *LAR, not each [voice] autosegment. The markedness constraint, then, is interpreted in the way that is most similar to the Ident faithfulness constraints, which calculate faithfulness based on the segment rather than autosegments.[6]

Finally, AGREE is low ranked in such a language. As long as AGREE

[6] Although this may suggest that each segment has its own [voice] feature, in fact this interpretation of the markedness constraint does not necessarily support any representational claims. *LAR may evaluate voiced segments, not [voice] autosegments, resulting in two marks for a cluster of two voiced consonants even if doubly linked. This interpretation of markedness violations would be similar to that of the Ident faithfulness constraints, which evaluate segments and not autosegments.

Note that this interpretation of markedness is contrary to the analysis of Beckman (1995) who argues that a spread configuration in vowel harmony incurs only one violation of a *F constraint. I will not attempt to resolve this inconsistency here.

is at least lower than *LAR, assimilating [voice] will be impossible, since this induces additional *LAR violations, as seen in (12).

(12)

	IDOns	*Lar	Agree	IDLar
c. /rat.geber/				
☞ ra[tg]eber		*	*	
ra[dg]eber		*!*		*
ra[tk]eber	*!			*
d. /rundgang/				
run[dg]ang		*!*		
☞ run[tg]ang		*	*	*
run[tk]ang	*!			**

(13) Ranking for syllable-final devoicing:[7]
IDOnsLar ≫ *Lar ≫ Agree, IDLar

3.2. *Voice Unrestricted*

As long as IDLAR outranks both *LAR and AGREE, there will be faithfulness to underlying voicing in all positions. *LAR and AGREE are the constraints that could prompt violations of faithfulness; if they are lower ranked than IDLAR, faithfulness will have priority. Note that since IDOnsLar violations are a subset of IDLAR violations, the ranking of IDOnsLar will make no difference as long as IDLAR AGREE, *LAR. The reader can easily see that if the IDOnsLar column were moved to the bottom of the ranking in the following tableau, the result would be no different.

[7] Note that this ranking will also account for the many languages that prohibit laryngeal distinctions syllable-finally but do not show alternations. In OT, where constraints are on outputs only, these must have the same phonological analysis as German; they cannot be the result of a constraint on underlying forms, due to the assumption of the richness of the base. The lack of underlying voiced-final morphemes in, for example, Thai, is a result of unrelated facts about the morphology of the language (words are mostly monosyllabic, and thus do not show alternations that would lead to the positing of final voiced consonants in underlying forms), not something truly different about its phonology.

(14) Voice in Obstruents Unrestricted (English)

	IDOns	IDLar	*Lar	Agree
a. /pig/				
☞ pig			*	
pik		*!		
b. /pigpen/				
☞ pigpen			*	*
pikpen		*!		
pigben	*	*!	**	
c. /catbird/				
☞ catbird			*	*
cadbird		*!	**	
catpird	*	*!		
d. /pegboard/				
☞ pegboard			**	
pekboard		*!	*	*
pekpoard	*	*!		

(15) Ranking for unrestricted voicing:
IDLar ≫ *Lar, Agree
Ranking of IDOnsLar irrelevant

3.3. *No Voicing in Obstruents*

Languages with *LAR ranked above faithfulness will be the common type with no voiced obstruents. (See Maddieson 1984 for many examples, including Maori, Ainu, Arabela (Peru), Maung and many other Australian languages, etc.)

(16) No Voiced Obstruents (hypothetical inputs)

/big/	*Lar	IDOns	IDLar
☞ pik		*	**
big	*!*		
bik	*!		*
pig	*!	*	*

Summing up these first three grammars, then, we see that it is possible for a language to permit voicing anywhere, to prohibit voicing anywhere, or to allow voicing in the onset but not in the coda. However, the opposite pattern – voicing in the coda but not in the onset – is impossible, which is correct since there are no such languages. Even if we reverse the ranking of the ID and IDOns constraint there would be no ranking that gives this pattern; either we get voicing possible everywhere (17), or voicing prohibited entirely (18).

(17) Voicing Unrestricted (English)

/big/	IDLar	*Lar	IDOns
pik	*!*		*
☞ big		**	
bik	*!	*	
pig	*!	*	*

(18) No Voiced Obstruents (hypothetical inputs)

/big/	*Lar	IDLar	IDOns
☞ pik		**	*
big	*!*		
bik	*!	*	
pig	*!	*	*

AGREE will have no effect even if it is ranked above the faithfulness constraints as well. Since voiceless clusters obey both AGREE and *LAR, even high-ranked AGREE will not motivate retention of voiced obstruents.

(19) No Voiced Obstruents (hypothetical inputs)

	*Lar	Agree	IDOns	IDLar
c. /pik.ben/				
pik.ben	*!	*		
pig.ben	*!*			*
☞ pik.pen			*	*

Relative rankings of constraints lower than *LAR make no difference. Note that there are no languages with alternations like those shown in this tableau; since [voice] never surfaces, it would be impossible for a language with *LAR highest ranked to maintain underlying voiced consonants. By Prince and Smolensky's (1993) principle of Lexicon Optimization, the learner presented with the surface data of the language in (19) will postulate voiceless underlying forms. Nevertheless, given the assumption of richness of the base in OT, we must examine how a grammar handles all possible inputs (Prince and Smolensky 1993, Smolensky 1993, 1996). The treatment of voiced inputs in (19) argues that this is the correct grammar for a language with no voicing distinctions.

(20) Ranking for language without voicing distinctions:
*Lar ≫ IDOnsLar, IDLar
Ranking of Agree irrelevant

3.4. *Voice Assimilation in Obstruent Clusters*

Many languages show assimilation to the voicing of the last obstruent in a cluster. Sonorants do not participate in such assimilation.

(21) Yiddish voicing assimilation (Katz 1987)

[vog]	'weight'	[vokšoi]	'scale'
[briv]	'letter'	[briftreger]	'mailman'
[ayz]	'ice'	[ayskastn]	'icebox'
[bak]	'cheek'	[bagbeyn]	'cheekbone'
[zis]	'sweet'	[zizvarg]	'candy products'
[kop]	'head'	[kobveytik]	'headache'

The behavior of word-final consonants is an issue of considerable relevance to the analysis of voicing assimilation. The most well-known cases of these languages also have word-final neutralization. This allowed Mester and Ito (1989) to suggest that voicing assimilation was a combination of syllable-final neutralization and spread of [voice], thus allowing us to maintain that [voice] is a privative feature – a desirable result for other reasons. This idea was taken up and elaborated by Lombardi (1991, 1995a) and Cho (1990). Because these theories all achieve 'assimilation' to voicelessness as a consequence of syllable-final devoicing, rather than spread of a value [-voice], they predict languages with voicing assimilation to always have word-final devoicing, since word-final consonants are syllable-final; Polish and Dutch are languages of this type. However, as Cho and Lombardi both found, this correlation does not always hold. It is not uncommon for a language to have voicing assimilation yet retain word-final voice, as seen in the Yiddish data above and in other type (e) languages from Lombardi (1991, 1995a).

Both Cho and Lombardi need some additional mechanism to account for this; for example, Lombardi (1991, 1995a) proposes Final Exceptionality, a feature-level analog of final extrametricality, as a way of retaining otherwise illicit [voice] in word-final position. As I will show, the present analysis can handle these cases by constraint reranking without any such additional stipulation. Languages with assimilation may either devoice or be faithful in this position; the proposed analysis will get the result that both are equally natural, while still allowing us to maintain the result that [voice] is privative.

3.4.1. *Assimilation in Clusters*

As described earlier, the constraint AGREE requires obstruent clusters to agree in voicing. This constraint will of course be in conflict with the Faithfulness constraints, which prefer underlying specifications to remain the same. But not all faithfulness constraints are equal. The subset relationship between IDOnsLar and IDLAR has the result that it is more important to be faithful to onset laryngeal specification than to coda (or elsewhere) specification. Thus, where the members of an input cluster disagree in voicing, the only way to satisfy AGREE will be for the coda to assimilate to the voicing of the onset:

(22) Direction of Voicing Assimilation (Yiddish)

/bakbeyn/	Agree	IDOns	IDLar
a. bak.beyn	*!		
☞ b. bag.beyn			*
c. bak.peyn		*!	*

In the tableau above, candidate (a) violates AGREE because it has an obstruent cluster that is not uniform in voicing. The cluster in candidate (c) is uniformly voiceless and so satisfies AGREE; but it has done this at the expense of being unfaithful to the onset's laryngeal specification, violating IDOnsLar and IDLAR. Thus, both (a) and (c) will lose to (b), where the coda has assimilated to the onset, satisfying both AGREE and IDOnsLar, and violating only IDLAR.

Like the neutralization and spread analysis of Lombardi (1991, 1995a), Cho (1990), Mester and Ito (1989), this analysis achieves assimilation to voicelessness without use of a feature [-voice], also due to the interaction of AGREE and the faithfulness constraints, as we see in (23).

(23) Assimilation to Voicelessness (Yiddish)

/vogšoi/	Agree	IDOns	IDLar
a. vogšoi	*!		
☞ b. vokšoi			*
c. vogžoi		*!	*

Candidate (a) violates AGREE, since the cluster does not agree in voicing. Candidate (c), with progressive assimilation, obeys AGREE, but has done so at the expense of violating both IDOnsLar and IDLAR, as it has voiced an underlyingly voiceless onset. Therefore, the winner will be (b). By devoicing the coda, this candidate has achieved satisfaction of AGREE – the whole cluster is voiceless – and it has achieved this by violating only IDLAR (the coda has changed from voiced to voiceless) but not IDOnsLar (the onset has not changed). This shows that we can maintain privative [voice] in OT under this analysis; the value [-voice] is not needed to account for voicing assimilation, as also argued in various pre-OT works (Cho 1990, Mester and Ito 1989, Lombardi 1991, 1995a). (See Lombardi 1995c for another argument for privative [voice] in OT.)

3.4.2. *Word-final Phonology in Languages with Voicing Assimilation*

As we have seen, then, for a language to have regressive obstruent voicing assimilation, the ranking will be AGREE, IDOnsLar ≫ IDLAR, *LAR. The relative ranking of IDLAR and *LAR will not be relevant for clusters, where high-ranking AGREE must be satisfied.

However, word-final consonants are not in an environment where AGREE can have an effect; thus, ranking of the other constraints will be crucial. As we saw above, IDLAR ≫ *LAR will result in coda faithfulness, and *LAR ≫ IDLAR will result in coda devoicing. Either one of these rankings of *LAR and IDLAR is possible in a language that has high-ranked AGREE and IDOnsLar, so both treatments of word-final consonants will be possible in languages that have voicing assimilation, as I will now show.

(24) Voice Assimilation, Final Neutralization (Polish)

	Agree	IDOns	*Lar	IDLar	
a. /klub/					'club'
klub			*!		
☞ klup				*	
b. /źabka/					'frog, dim.'
źabka	*!		*		
☞ źapka				*	
źabga		*!	**	*	
c. /prosba/					'request (noun)'
prosba	*!		*		
☞ proźba			**	*	
prospa		*!		*	
d. /nigdy/					'never'
☞ nigdy			**		
nikdy	*!		*	*	
nikty		*!		**	

As we see in this tableau, where there is no obstruent cluster, AGREE is irrelevant, so in word-final position (a) there is devoicing as a consequence of *LAR ≫ IDLAR. AGREE ≫ IDLAR means that there will be assimilation to voicelessness in (b): IDOnsLar is high ranked, so AGREE cannot be satisfied by spreading [voice] to the onset; however, AGREE can be satisfied, at the cost only of a low-ranked IDLAR violation, by devoicing the coda. However, we do get syllable-final voiced consonants where they are a consequence of assimilation, in (c, d): Satisfying *LAR (by leaving the coda voiceless) is not possible because it is more important to satisfy AGREE and IDOnsLar: thus we get a cluster that shares the [voice] of the onset.

(25) Ranking for assimilation and word-final devoicing:
IDOnsLar, Agree ≫ *Lar ≫ IDLar

Next, we turn to the Yiddish type of language. To have word-final faithfulness the language must have IDLAR ≫ *LAR; this does not conflict with the ranking that gives assimilation:

(26) Voice Assimilation, Word-Final Faithfulness (Yiddish)

	Agree	IDOns	IDLar	*Lar
a. /vog/				
☞ vog				*
vok			*!	
b. /vogšoi/				
vogšoi	*!			*
☞ vokšoi			*	
vogžoi		*!	*	**
c. /bakbeyn/				
bakbeyn	*!			*
☞ bagbeyn			*	**
bakpeyn		*!	**	
d. /ayzbarg/				
☞ ayzbarg				**
aysbarg	*!		*	*
aysparg		*!	**	

The majority of the interactions are the same here as in the last tableau: In both rankings, obeying AGREE is more important than avoiding additional *LAR violations, due to AGREE ≫ *LAR, and assimilation is regressive due to the relationship between IDOnsLar and IDLAR, which favors preserving onset voicing over preserving coda voicing. Thus, we get regressive voicing assimilation in clusters (b, c). But for obstruents that are not in clusters, where AGREE is not at issue, the rankings differ. In (24), *LAR ≫ IDLAR, so we have word-final devoicing. But here, as we see in (a), since IDLAR ≫ *LAR, voiced word-final consonants remain: it is more important to be faithful to an underlying [voice] specification than to obey *LAR by eliminating it.

(27) Ranking for assimilation and word-final faithfulness:
IDOnsLar, Agree ≫ IDLar ≫ *Lar

Thus, under this analysis assimilation combines equally naturally with either word-final devoicing or word-final faithfulness by simple constraint reranking. No additional mechanisms are required for either type of language, which correctly reflects the fact that they seem to be equally natural.

3.4.3. *Phonology of Word-medial CN Clusters in Languages with Voicing Assimilation*

Another issue in a language with obstruent voicing assimilation is what happens in medial obstruent-sonorant clusters. In previous neutralization and spreading analyses of voicing assimilation, if a CN cluster were heterosyllabic, it was predicted that it had to contain a voiceless obstruent, since the first consonant was syllable-final. However, languages like Yiddish and Serbo-Croatian allow a voicing distinction in medial CN clusters:

(28) Yiddish CN clusters

[mitniten]	'co-respondent'	[nudnik]	'nudnik'
[žukmaxer]	'bugmaker'	[zegmaxer]	'sawmaker'
[overzmanik]	'obsolete'	[aropnemen]	'take off'

Lombardi (1991, 1995a) argues that these clusters are onsets, and thus are predicted to allow voicing distinctions. An advantage of the present analysis is that this assumption about syllabification is no longer necessary. In fact, languages of Type B will retain voicing in such clusters even if heterosyllabic, due to the ranking IDLAR ≫ *LAR:

(29) Behavior of CN Clusters

	IDLar	*Lar
a. /mitniten/		
☞ mit.niten		
mid.niten	*!	*
b. /nudnik/		
☞ nud.nik		*
nut.nik	*!	

Thus, again the predictions of this theory seem to be correct. The presence of voicing assimilation is not erroneously predicted to cooccur only with devoicing in CN clusters.[8]

[8] Another possible example of this type is Hungarian (see Lombardi 1991). In Lombardi (1995a) I exclude this example from the typology on the basis of Vago's (1980) claim that assimilation is optional, but Gyula Zsigri (p.c.) informs me that most Hungarian linguists believe it to be obligatory. There are also languages with assimilation and final devoicing that seem to allow voiced C–N clusters in at least some circumstances. The cases I know of are Sanskrit and Catalan. See Lombardi (1991) for more detail, where I argue that the clusters are onsets; if this is correct, then a voicing distinction in the C is predicted to be possible by any theory.

3.5. *Swedish*

There is one remaining ranking that has not yet been addressed, and one language appears to exemplify this grammar. Swedish has been described as having bidirectional spread of [-voice]; in other words, a voiced obstruent devoices next to a voiceless obstruent (data from Hellberg 1974, Stephen Anderson p.c.).[9]

(30)a. Regressive assimilation to voicelessness

hög	[hö:g]	'high'	
högtid	[hœk:ti:d]	'festival'	
högfärdig	[hœk:fæ:dig]	'self-conceited'	
vigsel	[vik:səl]	'marriage'	*viga* 'to marry'
klädsel	[klɛt:səl]	'dressing'	*kläda* 'to dress'

b. Progressive assimilation to voicelessness

dag	[da:g]	'day'
tisdag	[tis:ta]	'Tuesday'
skog	[sku:g]	'forest'
skogs	[sku:ks]	(genitive)
skogsbrand	[skuk:spran:d]	'forest fire'

Preterite underlying -de, devoices to -te:

läste	'read'	*sylde*	'covered'
stekte	'fried'		

c. Voiced clusters: no change

äga	'to own'	*ägde*	(preterite)
väve	'to weave'	*vävde*	(preterite)

(Hellberg refers to the geminate consonants as tense; some of these forms

[9] In previous work I argued that Swedish word-internal clusters show assimilation to [+voice] only, following the description in Sigurd (1965). But Hellberg (1974) claims that orthographic mixed-voice word-internal clusters show the same devoicing as the examples in (31). I assume now that Hellberg is the more accurate source, since a more careful transcription is used and there is explicit discussion of the morpheme boundary facts. Assimilation to [+voice] only is predicted not to exist under the present analysis. The only other possible case is Ukrainian. Bethin (1987) argues following work by Andersen that voicing assimilation in Ukrainian is a purely phonetic process following from a rule that laxes syllable-final consonants. However, see also Butska (1998), who provides an OT analysis of Ukrainian assuming that the relevant feature is [voice] and that the constraints proposed in this paper should be modified to include a MaxVoice constraint, which is also argued to exist by Lombardi (1995c, 1998).

also have a variant with a short, lax devoiced consonant and a preceding long vowel.[10])

In a rule-based framework, a mirror image rule is needed to account for this pattern. Under the present analysis no special mechanism is required. This pattern will be found when the constraints are ranked as in the following tableau. (I abstract away from the variation in consonant tenseness/gemination; *LAR violations are noted for the clusters only.)

(31) Bidirectional Cluster Devoicing (Swedish)

	Agree	IDLar	*Lar	IDOnsL
a. /sku:g/				
☞ sku:g			*	
sku:k		*!		
b. /vigsəl/				
vigsəl	*!		*	
☞ viksəl		*		
vigzəl		*	*!*	*
c. /stekde/				
stekde	*!		*	
stegde		*	*!*	
☞ stekte		*		*
d. /ägde/				
☞ ägde			**	
äkde	*!	*	*	
äkte		*!*		*

As we see in (a), word-final consonants remain voiced, since IDLAR is

[10] The tense/lax distinction correlates predictably with consonant length and in most cases we appear to be able to abstract away from it in looking at the devoicing rule. There is one type of case where this may not be possible. In certain clusters Hellberg claims that voicing assimilation is only partial, for example:

(i) [bygd] 'district' genitive [bygts]

Hellberg argues from these cases that the voicing assimilation rule must refer to the feature [tense] as well as [voice]. All the problematic forms are word-final rather than word-internal clusters, where additional constraints are likely to be relevant (see, for example, in the analysis of English in section 3.6). A full resolution of this would require an examination of the conditions for gemination in Swedish, which appear to involve both stress and morphological structure; and the exact nature of a possible tense/lax distinction in consonants, which is an unresolved issue.

high ranked. When two voiced consonants come together, as in (d), the faithful output obeys both AGREE and IDLAR, so there is no high ranked motivation to be unfaithful to the underlying specifications. The interesting cases are (b), with a voiced-voiceless sequence, and (c), voiceless-voiced. High ranked AGREE rules out the faithful outputs. Either kind of assimilation – to voicelessness or to voicing – will change one of the consonants in the cluster, resulting in one IDLAR violation. Thus, the decision must be passed on to *LAR, which decides in favor of the voiceless cluster in both cases. Because IDOnsLar is lowest ranked, there is no constraint that favors one *direction* of assimilation over another; instead, *LAR favors assimilation to the unmarked state, voicelessness, regardless of direction.

The rarity of this pattern may be of significance. This is the only known pattern that requires IDLAR to be ranked above IDOnsLar. All other languages discussed have rankings that fall into the following categories:

1. The relative ranking of IDOnsLar and IDLar does not matter
2. IDOnsLar and IDLAR are separated by another constraint, and IDOnsLar is higher: IDOnsLar $\gg$ C $\gg$ IDLAR.

The grammars in the first category would give the same results if there were a strict ranking IDOnsLar $\gg$ IDLAR, although this ranking cannot be proven from the voicing assimilation data. Swedish is the only language I have found that *requires* the opposite ranking of these two constraints. The rarity of this type of assimilation suggests that although the ranking IDLAR $\gg$ IDOnsLar is not impossible, perhaps there is something marked about it. Such a ranking does seem somewhat counterintuitive given the general picture elsewhere that onset voicing is more important than voicing in other positions. Absent a theory of the markedness of rankings, this must remain speculative, but it suggests that such a theory may be required.

To sum up so far, the proposed constraints account for all the types of languages described in Lombardi (1991, 1995a, b, c). They do so without the need for special devices for the Yiddish type of pattern. They also predict the existence of a pattern not discussed in earlier work, which is exemplified by Swedish. I will now turn to the question of how the analysis handles generalizations about the direction of assimilation.

3.6. *Direction of assimilation*

The licensing analysis of Lombardi (1991, 1995a, b, c) goes some way towards explaining the dominance of laryngeal contrasts in the onset over those in the coda. However, in that analysis the rule of voicing assimilation still must stipulate direction. The wellformedness constraints alone could not prevent coda voiced obstruents from spreading [voice] to an onset, as this would result on the surface in the same well-formed doubly linked structure that results from regressive assimilation.

Thus, the earlier analysis still needs to resort to stipulation to account for the fact that voicing assimilation is overwhelmingly regressive in direction. (As do all previous analyses; see, for example, Mohanan 1993 for discussion). In contrast, the present analysis predicts that when only these basic constraints are sufficiently high ranked to be active, only regressive assimilation will be possible.

However, because the AGREE constraint is not inherently directional, progressive assimilation will still be possible, but only if higher-ranked constraints intervene to override the effects of IDOnsLar. This appears to make the correct empirical predictions. In all languages I know of where voicing assimilation simply applies to all clusters with no further restrictions on environment, it is regressive. All the cases of progressive assimilation I have found, in contrast, have some further morphological or phonological restrictions on the context of assimilation, showing the action of additional constraints. For reasons of space I cannot give detailed analyses of all of these examples, but I will present one and describe others.

The English plural provides a simple case of progressive voicing assimilation. I will account for this alternation by formalizing within OT the analysis proposed by Mester and Ito (1989; see also Lombardi 1991). Mester and Ito assume that the underlying form is voiced /z/ and so need to account for progressive voicing assimilation after voiceless consonants as in *cats*, and the retention of voicing in *pigs*. They propose that this is due to a universal syllable-wellformedness condition noted by Harms (1973) and by Greenberg (1978):

(32) Harms' generalization:
Voiced obstruents must be closer than voiceless to the syllable nucleus.

Thus, a form like the following is universally ruled out:

(33) *[kætz]

Adding this as a top-ranked constraint to the ranking already required for English will account for these facts. English after Level I has no restrictions on the distribution of voiced and voiceless obstruents, and so has the ranking IDOnsLar, IDLAR ≫ *LAR ≫ AGREE (Only the relevant constraints for this example are shown in the following tableau).

(34)

/kæt+z/	Harms' genl.	IdentLar	*Lar
a. kætz	*!		*
b. kædz		*	*!*
☞ c. kæts		*	

Candidate (a) violates the universal Harms's generalization, so the only possibilities are the voice-agreeing candidates (b, c). Both of these violate voice faithfulness for a single segment, so the decision falls to *LAR, which chooses the voiceless cluster.

(35)

/pIg+z/	Harms' genl.	IdentLar	*Lar
☞ a. pIgz			**
b. pIks		*!*	
c. pIgs		*!	*

In this tableau we see that, correctly, when the voiced ending is added to a voiced consonant there is no change. There is no motivation to change from the faithful candidate (a), since it does not violate top-ranked Harms' generalization. Because faithfulness to voicing is higher than *LAR, the faithfulness violations in (b, c) are fatal.

The English example, then, shows the action of an additional high-ranked constraint. Other cases of progressive voicing assimilation similarly show restrictions to special circumstances. Yiddish shows progressive assimilation with only one suffix, for example, and Dutch only when the second consonant is a fricative (see Lombardi 1997 for data and analyses.) Polish [r], where it is subject to a palatalization requirement which also results in change to an obstruent, undergoes progressive voicing assimilation (see Bethin 1992 and Lombardi 1991 for data). In all of these languages assimilation is regressive in all other contexts. Other cases restricted to certain morphological environments are the Dutch past tense morpheme (Lombardi 1991, 1995a, b, c and references therein) and Athapaskan (prefix-stem boundary only, Rice 1993).[11]

4. Complex Clusters

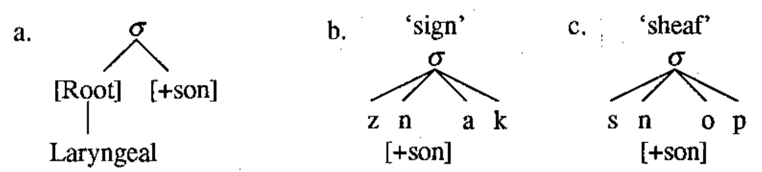
The examples so far have involved only single onset and coda consonants, to concentrate on the overall typology. This section will address the application of the constraints to longer clusters.

4.1. *Complex Onsets*

First, I will examine complex onsets in languages with voicing assimilation, with data from Polish (from Gussman 1992; Bethin 1992; see Lombardi 1991, 1995a for more detailed discussion).

First, we can see that the constraints will maintain a voicing contrast, as required, in obstruent sonorant-clusters. Voicing will not spread from sonorants here because as we can see from the following representations, the obstruents in such clusters are in the position as stated in (1) (repeated here in (a)) where faithfulness is required:

(36)



Thus, the IDOnsLar constraint will be violated if the voicing of these obstruents is changed. (Recall also that the AGREE constraint requires voicing agreement in obstruent sequences only; it is silent on obstruent-sonorant sequences such as these). The result is seen in the following tableaus.

[11] A final case that is not dealt with in Lombardi (1997) is that of Turkish, which shows progressive devoicing of voiced obstruent-initial suffixes. This case appears to be most similar to the analysis of Dutch in that paper, but I have been unable to confirm an analysis because the sources are contradictory about what clusters are allowed word-internally. For example, Lees (1961) and Underhill (1976) claim there are no voiced obstruents before another consonant; but Inkelas and Orgun (1993), and Inkelas, Orgun and Zoll (1994) claim there are some words with voiced codas and apparently with voiced clusters. Many of the words they cite are obvious loans and others are marked as 'learned' in Turkish dictionaries.

(37)

/znak/	Agree	IDOns	*Lar	IDLar
☞ a. znak			*	
b. snak		*!		*

In (b), the /z/ is devoiced; this is fatal, since it is in the position where faithfulness to voicing is required. AGREE is not violated, as this is not an obstruent sequence; the violation of *LAR is lower, and so has no force. Thus, voicing is maintained in this cluster.

(38)

/snop/	Agree	IDOns	*Lar	IDLar
☞ a. snop				
b. znop		*!	*	*

Again, the IDOnsLar violation in this case is fatal; since AGREE does not demand that this cluster agree in voice and *LAR is lower ranked, there is no higher-ranked motivation for violating faithfulness.

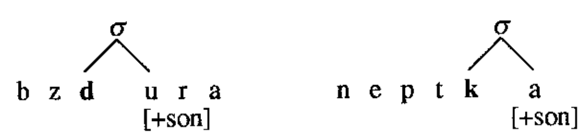
Next, we look at complex obstruent clusters, which always agree in voicing.

(39)

[veš]	'louse'	[fšɨ]	gen.sg
[stobow̃]	'with you'	[zbratem]	'with (my) brother'
źa[b]a	'frog'	źa[pk]a	'small frog'
ró[zg]a	'rod'	ró[štšk]a	'small rod'
wo[d]a	'water'	wó[tk]a	'vodka'
ne[ptk]a	'twit, gen.sg.'	[bzd]ura	'nonsense'

We see from (39) that it is the final obstruent in the cluster that determines the voicing of the entire cluster. In rule-based terms, the final consonant in the cluster is the one that triggers assimilation; in terms of the present analysis, we see that this is the consonant in the position where faithfulness is required by IDOns:

(40)



AGREE will require agreement in such clusters; IDOns requires faithfulness to the voicing of the last obstruent in the sequence; thus the optimal candidate will be the one where the entire cluster agrees in voicing with the final consonant in the cluster. This will be true no matter what the underlying specification for previous consonants in the cluster. We can see this by testing various possible underlying forms for an example like *[bzd]ura* 'nonsense'. The final consonant of the cluster must be voiced in the underlying form of this word; as the following tableaus show, the previous consonants will assimilate to it no matter what their underlying specification for voicing is. (Aside from the faithful output I consider only outputs that agree in voicing, as all others are ruled out by high-ranked AGREE.)

(41)

	Agree	IDOns	*Lar	IDLar
a. /psdura/				
psdura	*!		*	
☞ bzdura			***	**
pstura		*!		*
b. /bsdura/				
bsdura	*!		**	
☞ bzdura			***	*
pstura		*!		**
c. /bzdura/				
☞ bzdura			***	
psdura	*!		*	**
pstura		*!		***

We can see, then, that this constraint ranking will ensure that complex obstruent clusters will always agree in voicing with the last obstruent in the cluster, regardless of the input laryngeal state of the other consonants in the cluster; the reader can easily verify that the result in tableau (41) will also hold if the cluster is word-medial. The literature on Polish does not agree on how medial complex clusters are syllabified and there may in fact be surface variation in syllabification in some cases (see Bethin 1992 section 1.2.5 for some discussion). Since the constraints are not concerned with syllable position, they will handle medial clusters correctly regardless of syllabification.

The constraints also make a prediction about languages like German, which have final neutralization and no voicing assimilation. Mixed-voiced onsets are predicted to be possible, as there is no incentive for them to agree or to devoice, as seen in (42). This seems to be correct, as clusters like [tsv, kv] are possible.[12]

(42)

/tsvay/	IDOnsLar	*Lar	Agree	IDLar	
☞ tsvay		*	*		'two'
tsfay	*!			*	
dzvay		**!		*	

The hypothetical input in (43) shows that voiced onsets are not possible, which also seems to be correct. Although German does not have any morphology suitable for showing the alternation in this tableau, the ranking gives the correct distributional effect that we will see voiceless-voiced but no voiced-voiced obstruent onset clusters.

(43)

/gvay/	IDOnsLar	*Lar	Agree	IDLar
gvay		**!		
☞ kvay		*	*	*
kfay	*!			**

4.2. *Complex Codas*

The proposed constraints correctly yield devoicing of word-final obstruent clusters in languages with final devoicing, as seen in the following tableaus.

(44) Final neutralization ranking (German)

/jagd/	IDOnsLar	*Lar	Agree	IDLar
jagd		*!*		
☞ jakt				**
jagt		*!	*	*
jakd		*!	*	*

[12] Mixed-voice clusters in the opposite direction – e.g., onset *gf* – are ruled out by the Harms (1973) constraint discussed in section 3.6.

(45) Assimilation and final neutralization (Polish)

/muzg/	Agree	IDOnsLar	*Lar	IDLar
muzg			*!*	
☞ musk				**
muzk	*!		*	*

'brain'

A more interesting situation holds in languages with assimilation and word-final faithfulness like Yiddish and Serbo-Croatian. Such languages allow both voiced and voiceless final clusters. As we see in the following Serbo-Croatian examples, the ranking for such languages correctly gives faithful outputs for underlyingly voiced clusters:

(46)

/grozd/	Agree	IDOnsLar	IDLar	*Lar
☞ grozd				**
grozt			*!*	

'bunch of grapes'

However, if the input clusters have mixed voicing, the situation is more complicated. In a two-consonant cluster, the constraints correctly predict devoicing of the cluster, as we see in the following examples. (Example (47a) from Yiddish; Romanian and Serbo-Croatian do not appear to have suitable morphology to test these predictions.)

(47)

	Agree	IDOnsLar	IDLar	*Lar
a. /zog+t/				
zogt	*!			*
zogd			*	*!*
☞ zokt			*	
b. /pikd/				
pikd	*!			*
pigd			*	*!*
☞ pikt			*	

'you say'

In these clusters, any change to satisfy AGREE is a violation of IDLAR. Thus, the decision is passed on to lower-ranked *LAR, resulting in the unmarked voiceless cluster being optimal regardless of the relative order of the input voiced and voiceless consonants. The second example (47b) is hypothetical; Yiddish appears to have no voiced obstruent-only suffixes, and in fact this is more or less expected given the predicted pattern in

(47). Since such suffixes would always devoice, there would be no evidence for a language learner to conclude that they were underlyingly voiced. We would thus only see underlying forms like (47b) in a language where that voiced obstruent suffix could also sometimes be followed by a vowel-initial suffix, allowing the underlying voicing to surface, e.g., *pik+d+a*, and providing the required evidence for underlying voicing. Since Yiddish morphology happens not to have these sequences, all of its obstruent-only suffixes are underlyingly voiceless.

Finally, if we look at longer clusters, we see that there is an important argument for revising our notions of how featural faithfulness is calculated. McCarthy and Prince's (1995) Ident constraints calculate violations by segment. Under this interpretation, if the underlying number of voiced and voiceless consonants differs, the optimal output depends on the number of faithfulness violations incurred:

(48)

	Agree	IDOnsLar	IDLar	*Lar
/pigds/				
pigds	*!			**
☞ pigdz			*	***
pikts			*!*	
/piktz/				
piktz	*!			*
pigdz			*!*	***
☞ pikts			*	

Since each change of voicing incurs an Ident violation, the optimal output is the one with the fewest Ident violations: so the voicing of the cluster will be determined by whether there are more voiced or more voiceless consonants underlying. The prediction of the Ident constraints, therefore, is that in the absence of high-ranking constraints enforcing a certain direction of assimilation, the output of assimilation will depend on whether the input contains an odd or even number of consonants. This prediction is one that does not depend on one's theory of assimilation: it follows from the formulation of Ident constraints, which are calculated by segment, that number of segments might sometimes matter.

Although it is not possible to construct the examples that would allow us to test this prediction in Yiddish, it seems highly implausible; no known phonological processes distinguish odd and even numbers of segments. In order to solve this problem it seems that we will need a theory of featural faithfulness that gives somewhat more attention to the feature itself and not simply to the segment. MaxFeature constraints, argued for by Lombardi (1995c), LaMontagne and Rice (1995), and Causley (1996), are a step in this direction. However, if MaxF constraints are to replace Ident, we will need additional constraints regulating the association of features as well as whether a feature simply surfaces or not, since features do not move freely from one segment to another (some such constraints are proposed by Ito, Mester, and Padgett 1995).

The examples here clearly do not give sufficient evidence to work out the details of such a theory, but it will be important to take them into account in further research into featural faithfulness. Given the subset of the logical possibilities that we do see in Yiddish, it seems likely that all such mixed-voice clusters would devoice word finally, since our expectation is that number of consonants should not matter, and we know there is devoicing in the cases like (47a). This suggests that the feature faithfulness constraints need to be interpreted so that any change in feature association returns a single violation mark. This is a more feature-centered than segment-centered view: essentially, any change in the underlying associations of the [voice] autosegment constitutes a violation:

(49) Input — One Faith violation each for outputs:

Input				
/pig ds/	pigts	pikds	pikts	pig d z
[voice]	[voice]	[voice]	[voice]	[voice]

As we see in the following tableau, this will give devoicing for all possible combinations of underlying word-final obstruents. The results will then be the same as in the two-consonant clusters (47) above: since any change is a violation, the decision is passed to *LAR.

(50)

	Agree	IDOnsLar	FaithLar	*Lar
/pigds/				
pigdz			*	*!**
☞ pikts			*	
/piktz/				
pigdz			*	*!**
☞ pikts			*	

This change in our interpretation of featural faithfulness would not change the results in any other situation discussed in this paper. As is clear from

(46), it will still allow maintenance of *underlying* word-final voiced clusters, since the additional violations incurred under the old interpretation of IDLAR were superfluous in any case. Nor will it change the output in situations like the Polish complex onsets in (41), or the cases in (44) and (45), word-final clusters in other grammars, since there IDLAR is so low ranked that no change in the status of those violations can make a difference. This will also have no effect on our constraint IDOnsLar, as this is already a constraint that calculates violations incurred by failure to maintain an underlying association.[13]

5. Conclusion and Remaining Questions

This paper has argued that the direction of voicing assimilation of consonant clusters is a result of the interaction of a constraint requiring voicing agreement (AGREE) with constraints on positional faithfulness (IDOnsLar, IDLAR). It has also been shown that syllable-final neutralization is a result of the interaction of these faithfulness constraints with the markedness of laryngeal features (*LAR). Thus, these laryngeal alternations can be seen as due to conflicts among markedness and faithfulness constraints. The constraints *LAR and AGREE describe preferred, unmarked configurations: voicelessness for obstruents, and voicing agreement in adjacent obstruents. But these unmarked configurations will only be able to surface when faithfulness constraints do not dominate. And the environments of the alternations – the fact that both devoicing and assimilation affect coda consonants – will be due to positional requirements of faithfulness: the primacy of faithfulness to onset distinctions.

[13] Languages with faithful voicing present a final unresolved question for complex onsets and codas. The constraints as stated predict that mixed voice clusters should be possible: inputs like /sbit/, /pigs/ will be realized faithfully under the ranking IDOnsLar, IDLAR $\gg$ *LAR, AGREE, as in English, but these are not possible English forms. As seen in section 3.6, the word-final cluster may have another explanation. The word-initial cluster may suggest that there is also a need for a constraint requiring tautosyllabic clusters to agree in voicing. This would do little to change the total typology: we would only be able to see its effect in languages with the English ranking and in onsets in languages with the German ranking. Thus only a limited additional variability would be predicted: that languages like German could differ in whether onsets agree in voicing, and that languages like English could differ in whether tautosyllabic clusters must agree. In all other grammars the effects of any tautosyllabic agreement constraints would be masked by other constraints – for example, by high-ranked AGREE, which would affect both hetero- and tautosyllabic clusters – and thus it is difficult to find the data to test the predictions. (Mixed-voice obstruent clusters seem to be exceedingly rare: Greenberg (1978), in a survey of 104 languages, finds only eight languages that may have them, and considers all of them dubious.) There are also other restrictions on clusters that may interact crucially with the voicing facts, for example, that in English all the relevant onset clusters start with /s/.

The proposed constraints successfully account for the patterns of word-internal voicing assimilation and neutralization in (2). Rerankings of these constraints produce the attested patterns and do not produce other logically possible unattested voicing assimilation/neutralization patterns, such as neutralization in onset but not coda.

This analysis has successfully assumed that [voice] is a privative feature, showing that we can maintain this assumption in OT. An improvement over previous privative voicing analyses is the fact that no special mechanism is needed to account for the cross-linguistic variation in the behavior of word-final consonants in languages with voicing assimilation. Both word-final devoicing and word-final faithfulness can combine with voicing assimilation by simple constraint reranking.

Other phonological processes involving voicing do exist, of course, and remain to be accounted for; some limitations of scope are necessary for reasons of length and due to the fact that the extension of OT to segmental phonology is still in its first stages of development. This paper has been restricted to lexical voicing assimilation. A distinction between lexical and postlexical rules has been argued for in Lexical Phonology (see Kaisse and Shaw 1985 for a useful review), and has sometimes been argued to be needed in OT (see McCarthy and Prince 1993 for an example). It is not obvious that all diagnostics for such level differences necessarily carry over into a new framework, and the solution to the differences in OT need not involve derivational levels (see, for example, the work of Benua 1995). Nevertheless, within the facts of obstruent laryngeal phonology there seem to be a few clear and consistent empirical differences that correlate largely with the traditional lexical-postlexical diagnostics.

One example is the interaction of sonorant and obstruent voicing. It is possible for sonorants to spread their voicing regressively to obstruents across word boundaries (such as Warsaw Polish; see Lombardi 1991 for discussion); sonorants also appear to spread their voicing to obstruents in intervocalic voicing and postnasal voicing, which are allophonic in all but a limited number of well-known problematic cases (Japanese is one; see for example Ito, Mester, and Padgett 1995). I assumed above that the AGREE constraint referred only to obstruents, but these cases show that this may need to be stated as a more general voice agreement imperative that potentially affects sonorants but which is often restricted by constraints on interactions of sonorants and obstruents. (This would connect to work such as that on CV linkage discussed by Ito, Mester and Padgett 1995, attempting to account for the fact that more similar segments are more likely to interact.) The observation that postlexical assimilation possibilities are different could reflect a reranking option that is only possible at that level: lower ranking of the constraint on interactions of sonorants and obstruents, permitting broader effects of the AGREE constraint.

This paper also does not deal with apparent cases of reference to [-voice] in the phonology at the postlexical level. I argue that such cases exist in Lombardi (1996), as predicted by Lexical Phonology and some theories of underspecification, and that different feature specifications are available at the different levels.[14] I know of no languages that have this pattern lexically, so it seems to be correct that the constraints that I have proposed do not predict the existence of such a pattern word-internally.

The results of this paper also suggest as a direction for future research the extension of this analysis to other cases of assimilation. The idea of positional faithfulness has been shown to be useful to account for various phenomena, such as vowel harmony and other cases of positional neutralization in the work of Beckman (1995, 1996). However, it is clear that positional faithfulness constraints differ for different features, reflecting underlying phonetic differences in the salience of various types of distinctions in different positions (see Beckman 1996). It seems possible that parallel to the differences in positional faithfulness constraints, there may also be substantive differences in the constraints enforcing assimilation. The spreading imperative in this paper, AGREE, is stated very specifically to apply to certain features in a certain context. The phonology of Place assimilation seems to call for a very similar account, as Padgett (1995) independently argues. The important position for faithfulness to Place features is the same as for laryngeal features, and Padgett justifies a similar cluster assimilation constraint for Place. But assimilation of other features may be quite different. We can contrast another common type of assimilation, vowel harmony, which often extends across the whole word; voicing assimilation never does so. And while voicing often assimilates, assimilation of the other laryngeal features, aspiration and glottalization, is rare or nonexistent. Future research will need to account for these differences, as well as the generalization that assimilations are common and natural phonological alternations.

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[14] There is also an additional case, Makkan Arabic (Abu-Mansour 1995) which is argued to show regressive assimilation of [-voice] only by Gnanadesikan (1997). Abu-Mansour shows that this assimilation is postlexical, as predicted by Lombardi (1996).

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