Directional Footing, Degeneracy, and Alignment*

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0. Introduction

This paper argues from an Optimality Theory (OT; Prince & Smolensky 1991, 1993; McCarthy & Prince 1993a,b, 1994) perspective that no one-to-one correspondence exists between directional footing effects and individual constraints. Rather, the requirements of a single prosodic alignment constraint may result either in left-to-right or right-to-left footing, depending on its position in a constraint hierarchy relative to constraints which require syllable-to-foot parsing and binary foot structure. We show, furthermore, that an OT approach predicts a dependency between direction of footing and the treatment of stray syllables not predicted under other accounts.

Schematic examples illustrating directional footing appear in (1). Directional effects are apparent only in forms which cannot be parsed evenly into binary feet; for example, those containing an odd number of syllables in (1). Here, chains of feet give the appearance of being anchored at one edge and stretching as far as possible across the domain, producing effects of rightward or leftward movement. Stray syllables left over

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after binary feet have been formed may either be assigned to "degenerate" (sub-binary) feet, as in (1c,f); or they may not be assigned to feet at all, as in (1b,d).

(1)		*Left-to-Right*		*Right-to-Left*
	a.	(σ σ)(σ σ)	d.	(σ σ)(σ σ)
	b.	(σ σ)(σ σ) σ	e.	σ (σ σ)(σ σ)
	c.	(σ σ)(σ σ)(σ)	f.	(σ)(σ σ)(σ σ)

Directional effects such as those illustrated in (1) have traditionally been derived by constructing rhythmic structures sequentially and exhaustively across a metrical domain from either the left or the right (e.g. Liberman & Prince 1977; Hayes 1981, 1987, 1994; Prince 1983; Hammond 1984, 1990; Selkirk 1984; Halle & Vergnaud 1987; Halle 1990; Kager 1989; Hewitt 1992; Idsardi 1992). In cases where exhaustive parsing into binary feet was not possible, the fate of stray syllables (i.e. (1c,f) vs. (1b,e)) was taken to depend on language-specific tolerances for sub-binary feet, usually controlled by a parameter independent of that for directionality (cf. the Degenerate Foot Parameter of Hayes 1994 or the Minimal Structure Parameter of Crowhurst 1993).

Recent work in OT claims that directional footing effects are best captured by the constraints All-Feet-Left (Ft-Left) and All-Feet-Right (Ft-Right) in (2) (e.g. McCarthy & Prince 1993b, 1994; Kirchner 1993; Cohn & McCarthy 1994; Crowhurst & Hewitt, in press; Hewitt 1994a; Kager 1994).

(2)			
	a.	*All-Feet-Left:*	Align(Foot, L, PrWd, L)
	b.	*All-Feet-Right:*	Align(Foot, R, PrWd, R)

Ft-Left and Ft-Right are members of the Generalized Alignment family. The interpretation of alignment constraints is formally stated in (3) (McCarthy & Prince 1993b:2).

(3) *Generalized Alignment*

Align(Cat1, Edge1, Cat2, Edge2) $=_{def}$

$\forall$ Cat1 $\exists$ Cat2 such that Edge1 of Cat1 and Edge2 of Cat2 coincide.

Where

Cat1, Cat2 $\in$ PCat $\cup$ GCat

Edge1, Edge2 $\in$ {Right, Left}

(PCat and GCat range over the sets of prosodic and grammatical categories, respectively.) Under this definition, the constraints Ft-Left and Ft-Right in (2) require that every foot in a metrical representation be left/right-aligned with a prosodic word (PrWd). Thus, when either Ft-Left or Ft-Right is highly ranked in a grammar, all feet in the representation are "packed" to the left or to the right within the PrWd, mimicking effects of directional footing.

This paper argues that the relationship between the alignment constraints in (2) and directional footing is more complicated than has been envisioned. In fact, the OT account presented here reveals directional effects to be epiphenomenal: either of the constraints in (2) may yield rightward or leftward footing, depending on its interaction with constraints requiring syllable-to-foot parsing and binary foot structure (see below).

We also show that directionality and stray syllable parsing at edges are dependent: right-to-left and left-to-right effects under Ft-Left dominance co-occur with *either* the presence or the absence of a degenerate foot, but *not with both*. This relationship is inverted when Ft-Right dominates Ft-Left. One outcome of this study is that interactions among a small number of constraints leads to a modified typological view of metrical patterns familiar from earlier work. When factors of cross-linguistic markedness are considered, the typology introduced here (though simplified for present purposes) more closely reflects what we know of metrical systems across languages than some earlier typologies.

For the remainder of the paper, we assume familiarity with the principles of Optimality Theory and with metrical theory more generally. The fundamental observations of the paper and an OT analysis are presented in ¤1. Predictions of the proposed account are compared with those of a parametric approach in ¤2, and implications for typology and language change are discussed. Concluding remarks are offered in ¤3.

1. Directional Effects, Alignment, and Degenerate Feet.

As noted earlier, Ft-Left and Ft-Right in (2) require that any feet present in a representation lie as close as possible to the appropriate edge of a PrWd. Following McCarthy & Prince (1993b), foot misalignments are assessed gradiently in terms of the category immediately dominated by Foot in the prosodic hierarchy (e.g. Selkirk 1984; Nespor & Vogel 1986, McCarthy & Prince 1986), so that one violation is incurred for every syllable standing between the L/R boundaries of any foot and a PrWd. Optimal representations with respect to Ft-Left and Ft-Right must therefore contain a single foot flush with the left or right edge, respectively, of a PrWd. The constraint whose interaction with Ft-Left and Ft-Right is crucial in determining whether footing is iterative or noniterative in a metrical system is *Parse-σ.* The version stated in McCarthy & Prince (1993b:11) appears in (3).[1]

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[1] The original motivation behind Parse-σ was the need to impose strict dominance relations between syllables and feet (as per the Strict Layer Requirement of Selkirk 1984). It has been assumed that when Parse-σ is violated, syllables are dominated by the PrWd (the "Weak Layering" option discussed by Hewitt 1992; It™ & Mester 1992). A problem with this second assumption emerges when we compare syllabic with segmental parsing: parsed segments are included in syllable structure whereas unparsed segments generally fail to surface. Unpublished work by Hewitt (1994a) and Hewitt & Crowhurst (in prep.) argues that grammars should distinguish between *parse* constraints, which demand inclusion in (though not immediate dominance by) some category, and *link* constraints, which insist on strict dominance from either the bottom up or the top down. Under this view, Link-σ-to-Foot requires that every syllable be dominated by a foot, while Link-Foot-to-σ requires that every foot dominate (at least) one syllable. Parse-σ could then be reserved for a weaker requirement that syllables be included in higher prosodic structure, a requirement that could be satisfied under PrWd domination. We note this important issue in passing; however, as the point is not crucial to the analysis presented here, we use Parse-σ, the more familiar constraint.

(3) *Parse-σ:* All σ must be parsed by feet.

Parse-σ introduces a conflicting demand that syllables must be included in feet. A violation is assessed for every syllable not meeting this requirement. The tableau in (4) shows that when Ft-Left outranks Parse-σ, the result is noniterative footing: the domination of syllables by feet is sacrificed to the left-edge requirement imposed by Ft-Left.[2,3]

(4) *Ft-Left È Parse-σ*

Candidates	Ft-Left	Parse-σ
✓ a. (σ σ) σ σ σ		***
b. σ σ σ σ σ		****! *
c. (σ σ)(σ σ) σ	*! *	*
d. (σ σ) σ (σ σ)	*! **	*
e. σ (σ σ)(σ σ)	*! ***	*

(Specification of headedness in feet is not a central issue in this paper, and is routinely suppressed to simplify discussion. By convention, dominance decreases from left to right in tableaux and in ranking statements such as *a È §*. A colon rather than *È* separates constraints which are not crucially ranked. Optimal forms are marked with the symbol

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2 If Ft-Left and Parse-σ are unranked, then *Struc-Ft, which penalizes the presence of feet in the representation, will force noniterative footing if is is ranked below Parse-σ. When two constraints are unranked, violations of both constraints count equally (Prince & Smolensky 1993; McCarthy & Prince 1993a). The tableau below shows that if Ft-Left and Parse-σ are unranked, then candidates (a) and (d) are tied with three violations across these two constraints. In this case, *Struc-Ft decides for the candidate with the fewest feet.

*Parse-σ : Ft-Left È *Struc*

Candidates	Parse-σ	Ft-Left	*Struc
a. (σ σ)(σ σ) σ	*	**	**!
b. (σ σ) σ (σ σ)	*	***!	**
c. σ (σ σ)(σ σ)	*	***!	**
✓ d. (σ σ) σ σ σ	***		*
e. σ σ σ σ σ	****! *		
f. (σ σ)(σ σ)(σ)		****! *	***
g. (σ)(σ σ)(σ σ)		****!	***
h. (σ σ)(σ)(σ σ)		****! *	***

3 When either Ft-Left or Ft-Right appears in one of the hierarchies discussed here, its opposite-edge counterpart, although not shown, should be assumed to rank lower in the hierarchy. All points illustrated using Foot-Left hold equally for Foot-Right when these constraints exchange positions in a hierarchy.

✓, and an exclamation point indicates a fatal violation which precipitates a candidate's expulsion from the optimal set.)

The optimal pattern in (4a) is characteristic of languages which display a single stress on the first or second syllable of a PrWd (depending on sensitivity to syllable weight and on whether feet have trochaic or iambic heads). A language whose pattern of exclusive word-initial stress is consistent with the presence of a trochaic foot at the left edge of the PrWd is Latvian. Examples from Fennell & Gelsen (1980:11,15,18,23) appear in (5).

(5) *Latvian* (Fennell & Gelsen 1980)

z—bs	(z—bs)	'tooth'
sl’kti	(sl’kti)	'badly'
j‡ut\O(a,ø)jums	(j‡ut\O(a,ø))jums	'question'
p‡l\O(i,ø)dzet	(p‡l\O(i,ø))dzet	'to help'
sk—lot\O(a,ø)jam	(sk—lo)t\O(a,ø)jam	'the teacher'

In contrast with (4), the hierarchical configuration Parse-σ È Ft-Left (dubbed "the alternator" by Kager 1994) yields the pattern of rightward *iterative footing* familiar from Pintupi (Hansen & Hansen 1969, Hayes 1994) and Diyari (Austin 1981, Poser 1989, Crowhurst 1994).[4] In the Pintupi examples in (6a), stress occurs on odd-numbered syllables counting from the left, but never on an ultima. Here, as many syllables as possible are assigned to feet, and all feet lie as close to the left edge of the PrWd as possible without overlapping.

(6)a. *Pintupi* (Hansen & Hansen 1969:163-5)

p‡\O(n,.)a	(p‡\O(n,.)a)	'earth'
tʲœ\O(t,.)aya	(tʲœ\O(t,.)a)ya	'many'
tʲ’tʲiw“nʲ4a	(tʲ’tʲi)(w“nʲ4a)	'boy's name'
w‡ntikˆti\O(r,ÿ)a	(w‡nti)(kˆti)\O(r,ÿ)a	'having left'
\O(t,.)’\O(l,.)i\O(r,ÿ)“4ulˆmpatʲu	(\O(t,.)’\O(l,.)i)(\O(r,ÿ)“4u)(lˆmpa)tʲu	'the fire for our ben

b. *Diyari* (Austin 1981:31)

k‡\O(n,.)a	(k‡\O(n,.)a)	'man'
p’nadu	(p’na)du	'old man'
4‡ndawˆlka	(4‡nda)(wˆlka)	'to close'

Directional effects are apparent only in forms with an odd number of syllables (e.g. Pintupi *(tʲœ\O(t,.)a)ya*). The significant metrical properties of such forms include

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4 The Diyari forms in (6b) are monomorphemic. The analysis of polymorphemic forms is complicated by the fact that monosyllabic suffixes do not take stress. More detailed OT analyses are provided in Crowhurst (1994) and Hewitt & Crowhurst (in prep.).

Many other examples of all iterative patterns discussed in this paper can be found in Hayes (1994), a fine crosslinguistic study of iterative stress languages.

left-to-right footing under Ft-Left and the absence of a sub-binary foot at the right edge (e.g. **(tʲœ\O(t,.)a)(yˆ)*). The second property, the absence of a peripheral degenerate foot, is due to the requirement that feet are binary, stated as *Foot Binarity (FtBin)* in (7) (from McCarthy & Prince 1993a,b).

(7) *Foot Binarity:* Feet are binary at some level of analysis (μ, σ).

Under FtBin, a violation is assessed for any foot dominating fewer than two elements.[5] Thus, when FtBin dominates Parse-σ, the result is that stray syllables are not included in foot structure. An analysis of the Pintupi pattern under the constraint hierarchy FtBin È Parse-σ È Ft-Left is given in (8).

(8) *FtBin È Parse-σ È Ft-Left*

Candidates	FtBin	Parse-σ	Ft-Left
✓ a. (σ σ)(σ σ) σ		*	**
b. (σ σ) σ (σ σ)		*	***!
c. σ (σ σ)(σ σ)		*	***! *
d. (σ σ) σ σ σ		**! *	
e. σ σ σ σ σ		**! ***	
f. (σ σ)(σ σ)(σ)	*!		******
g. (σ)(σ σ)(σ σ)	*!		****
h. (σ σ)(σ)(σ σ)	*!		*****

Three candidates violate FtBin, the highest-ranking constraint, and are immediately ejected from the field. All remaining candidates contain parse violations; the most serious violators, (8d,e), are excluded. The tie between (8a), (8b), and (8b) is broken by Ft-Left. Parse-σ dominance over Ft-Left is critical in this tableau. As noted in footnote 2, if Parse-σ and Ft-Left were unranked, then (8a) and (8d) would be tied with three violations each, under the assumption that violations of unranked constraints count equally. In that case, we would expect the tie to be broken by *Struc-Ft, forcing noniterative footing.

In (8), where FtBin is undominated, the candidates (8f,g,h) containing degenerate feet are rejected even though these are the only candidates in which all syllables are parsed. When FtBin is demoted to a position below Parse-σ, by contrast, two results follow. The first is the presence of sub-binary feet when optimal binary feet cannot be constructed. The second, more striking, outcome is a change in the direction of footing. The tableau in (9) shows that under the hierarchy Parse-σ È FtBin : Ft-Left, what emerges is not iterative left-to-right footing as in (8), but right-to-left footing instead. This tableau also shows that as long as Parse-σ is topmost, no crucial ordering between FtBin and Ft-Left is necessary.

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[5] Feet containing three elements would also count as a violation of FtBin under this definition. For arguments that FtBin should be refined into independent constraints, see Hewitt (1994a,b).

(9) *Parse-σ È FtBin : Ft-Left*

Candidates	Parse-σ	FtBin	Ft-Left
a. (σ σ)(σ σ) σ	*!		**
b. (σ σ) σ (σ σ)	*!		***
c. σ (σ σ)(σ σ)	*!		****
d. (σ σ) σ σ σ	*! **		
e. σ σ σ σ σ	*! ****		
f. (σ σ)(σ σ)(σ)		*	*****! *
✓ g. (σ)(σ σ)(σ σ)		*	****
h. (σ σ)(σ)(σ σ)		*	*****!

In tableaux (9), the five candidates with parse violations are eliminated early, since non-violating candidates exist. This time, FtBin does no work for us, as the remaining candidates are tied with a single FtBin violation each, and so the decision is passed to Ft-Left. It is worth noting that the tableaux in (8) and (9) provide an argument for the gradient assessment of alignment constraints, as originally proposed by McCarthy & Prince (1993b). These authors have more recently adopted the opposite stance in endorsing *categorical* evaluation, under which a single penalty is levied for any misaligned pair of constituents (McCarthy & Prince 1994). However, this method makes the wrong predictions concerning optimal candidates in the cases considered here. Under categorical assessment, when FtBin dominates Parse-σ and Foot-Left as in (8), both of the candidates (σσ)(σσ)σ and (σσ)σ(σσ) should emerge as optimal (each violating Ft-Left twice); in (9), where FtBin is ranked below Parse-σ, nothing would decide between the three candidates containing a degenerate foot, all double violators of Ft-Left, if no other constraints are considered. We know of no language exhibiting free variation among forms with these shapes.

A language whose stress pattern is consistent with the optimal pattern in (9g) is Weri (Boxwell & Boxwell 1966). Examples appear in (10).

(10) *Weri* (Boxwell & Boxwell 1966:88)

4ɪn't'p	(4ɪn't'p)	'bee'
k•lɪpŒ	(k•)(lɪpŒ)	'hair of arm'
ᴜl•.a'.m't	(ᴜl•)(a'.m't)	'mist'
ˆkᴜn•te'p‡l	(ˆ)(kᴜn•)(te'p‡l)	'times'

The presence of a single degenerate foot at the left edge in Weri is typical of a quantity-insensitive pattern where weight distinctions among syllables are either not present or ignored.

When All-Feet-Right (Ft-Right) in (2b) replaces Ft-Left as the dominant constraint in the preceding tableaux (8) and (9), the relationship between directionality and stray syllable (non)parsing is inverted: under Ft-Right, leftward footing effects must be accompanied by a failure to parse stray syllables, rightward footing by the presence of sub-binary feet.[6] A language illustrating the pattern of leftward footing with no sub-binary footing predicted under the hierarchy FtBin È Parse-σ È Ft-Right is Yakan (Behrens 1975). Examples appear in (11) (*j* is an alveopalatal affricate; *q* is a glottal stop).[7]

(11)	*Yakan*		(Behrens 1975:13-28)
	b‡gay	(b‡gay)	'friend'
	bag‡ykun	ba(g‡ykun)	'my friend'
	mˆkaj‡di	(mˆka)(j‡di)	'possible'
	mamˆgqak‡hin	ma(mˆgqa)(k‡hin)	'the one who told it'

Rightward footing with a final degenerate foot in odd-syllabled forms predicted under the hierarchy Parse-σ È FtBin : Ft-Right is exemplified by Ono (Phinnemore 1985, Hayes 1994) and Icelandic (çrnason 1980, Hayes 1994). Representative forms appear in (12).

(12)a.	*Ono*		(Phinnemore 1985:174)
	d•ne	(d•ne)	'my eye'
	‡ril•	(‡ri)(l•)	'I went'
	l—lotn•	(l—lot)(n•)	'many'
	m•sik•ne	(m•si)(k•ne)	'you will sit'
b.	*Icelandic*		(çrnason 1980:44)
	t‡ka	(t‡ka)	'to take'
	‡lmanˆk	(‡lma)(nˆk)	'calendar'
	‡lmanˆkannˆ	(‡lma)(nˆkan)(nˆ)	'calendar (ge. pl. def.)'

To sum up, the analysis presented here exposes the following relationships between constraint sub hierarchies and metrical patterning. (*Align* in (13) covers both Ft-Left and Ft-Right.)

(13)a. Align È Parse-σ: noniterative footing (independent of FtBin)

b. Parse-σ È Align: iterative footing in α direction and $*_{F}(\sigma)$ if FtBin È Parse-σ.
iterative footing in -α direction and ${}_{F}(\sigma)$ if Parse-σ È FtBin.

When Align dominates Parse-σ as in (13a), the outcome is noniterative footing, no matter where FtBin sits in the hierarchy. When Parse-σ outranks Align, as in (13b), the result is iterative footing. These observations are not new (see Kager 1994; McCarthy & Prince

6 As the selection of optimal candidates under Ft-Right dominance so exactly mirrors that when Ft-Left is dominant, we do not provide tableaux as these would add nothing to the points already made.

7 A third language which exhibits this pattern is Manam (Lichtenberk 1983, Halle & Kenstowicz 1991). Manam, recently re-analysed by Buckley (1994) in optimality-theoretic terms, is particularly interesting in that sub-binary feet are generally banned, but do surface when they are included in input representations, showing that FtBin, though highly ranked, must be dominated by a faithfulness constraint.

1993b, Cohn & McCarthy 1994; Crowhurst 1994, and Kirchner 1993 for a related analysis). The special contribution of this paper is the set of findings in (13b): when Parse-σ dominates Align,the direction of footing depends on the position of FtBin in the hierarchy. When FtBin outranks Parse-σ, footing is from left-to-right when Ft-Left is high, and from right-to-left when Ft-Right is high. However, when Parse-σ outranks FtBin, the direction of footing is reversed. This shift in directionality hinges on the presence of a sub-binary foot. When degenerate feet are absent under FtBin dominance, parse violations are pushed away from the relevant alignment edge, as the presence of unfooted syllables any further to the left (or right) introduces unnecessary violations of Ft-Left (or Ft-Right). But when a degenerate foot is unavoidable, as when FtBin is dominated by Parse-σ, the presence of the smaller foot at the relevant alignment edge *minimizes* Ft-Left (or Ft-Right) violations by decreasing the number of syllables between all subsequent feet and the beginning (or end) of the PrWd.

In a theory so richly endowed with constraints, one analysis might seem to work as well as another in predicting attested surface forms. Before proceeding, we argue that the analysis we have proposed is more parsimonious than an appealing alternative. The argument is that regardless of which other constraints may seem to play a role in the generation of iterative and noniterative footing, it is not possible to do without FtBin, Parse-σ, and Ft-Left (or Ft-Right). But, since these three constraints are sufficient to predict the attested patterns, the most parsimonious analysis does without extra baggage.

The best alternative analysis for iterative footing that we see would be one in which the constraints Initial-Foot, stated in (14), and Parse-σ are dominant, as any ranking of these produces multiple feet.

(14) *Initial-Foot:* Align(PrWd, L, Foot, L)

(Initial foot is the inverse of Ft-Left; it states that every PrWd must begin with a foot.) In the specific case where Initial-Foot outranks Parse-σ, inserting between them the constraint *Struc-Ft yields noniterative footing.[8] The tableau for noniterative footing under this analysis is shown in (15).

(15) *Initial-Ft È *Struc-Ft È Parse-σ*

Candidates	Initial-Ft	*Struc-Ft	Parse-σ
a. (σ σ)(σ σ) σ		**!	*
b. (σ σ) σ (σ σ)		**!	*
c. σ (σ σ)(σ σ)	*!	**	*
✓ d. (σ σ) σ σ σ		*	***
e. σ σ σ σ σ	*!		*****
f. (σ σ)(σ σ)(σ)		**! *	
g. (σ)(σ σ)(σ σ)		**! *	
h. (σ σ)(σ)(σ σ)		**! *	

8 *Struc-Ft assigns a penalty for every foot represented. Original motivation for constraints in the *Struc family was provided by Zoll (1993).

While this analysis has initial appeal, complications arise in the analysis of iterative footing. Initial-Foot and Parse-σ alone generate multiple feet, but they do not decide between the candidates (σσ)(σσ)σ and (σσ)σ(σσ). A directional bias could be introduced by including the constraint Align-Foot-Foot (Ft-Ft) in (16), which enforces end-to-end feet.

(16) *Align-Foot-Foot:* Align(Foot1, α, Foot2, -α) (α = L or R)

An analysis with Ft-Ft is attractive for two reasons: first, it requires that some edge α of Foot1 be aligned with the opposite edge of Foot2; it makes no difference to the outcome whether α is specified as L or R. Second, if FtBin dominates Parse-σ, Ft-Ft pushes parse violations to the edge furthest from the initial foot, doing some of the work of Ft-Left in tableau (8). No special ranking between constraints in the pairs Ft-Ft/Initial-Foot or Ft-Ft/Parseσ is required, but Ft-Ft may not dominate both Initial-Foot and Parse-σ as in that case, the completely unparsed candidate would be optimal. The tableau in (17) shows that when FtBin is undominated, the optimal candidate is (σσ)(σσ)σ, just as in tableau (8).

(17) *FtBin È Parse-σ: Initial-Foot È Ft-Ft*

Candidates	FtBin	Parse-σ	Initial-Ft	Ft-Ft
✓ a. (σ σ)(σ σ) σ		*		*
b. (σ σ) σ (σ σ)		*		**!
c. σ (σ σ)(σ σ)		*	*!	*
d. (σ σ) σ σ σ		**! *		*
e. σ σ σ σ σ		**! ***	*	
f. (σ σ)(σ σ)(σ)	*!			*
g. (σ)(σ σ)(σ σ)	*!			*
h. (σ σ)(σ)(σ σ)	*!			*

The tableau in (18) shows that when FtBin is demoted to a position below Parse-σ, however, the four constraints included so far do not choose between the three candidates which contain a degenerate foot.

(18) Parse-σ È FtBin È Initial-Foot È Ft-Ft

Candidates	Parse-σ	FtBin	Initial-Ft	Ft-Ft
a. (σ σ)(σ σ) σ	*!			*
b. (σ σ) σ (σ σ)	*!			**
c. σ (σ σ)(σ σ)	*!		*	*
d. (σ σ) σ σ σ	*! **			*
e. σ σ σ σ σ	*! ****		*	
✓ f. (σ σ)(σ σ)(σ)		*		*
✓ g. (σ)(σ σ)(σ σ)		*		*
✓ h. (σ σ)(σ)(σ σ)		*		*

Either Ft-Left or Ft-Right would choose among this set. Note, however, that the alternative analysis requires five constraints, Parse-σ, FtBin, Initial-Foot, Ft-Ft, and either Ft-Left or Ft-Right to perform the labour of only Parse-σ, FtBin, and Ft-Left (or Ft-Right) in the analysis proposed earlier. If we assume that analyses which posit fewer critical constraints and rankings are least burdensome for language learners, then the simpler analysis with only three constraints is to be preferred.[9]

In ¤2 we compare predictions which emerge under our analysis of iterative stress systems with predictions of a parameters approach to metrical footing.[10]

2. Implications for Typology and Change

The analysis presented in ¤1 predicts the same array of metrical patterns as any of several earlier theories which have sought to account for the same range of linguistic data. The typology (excluding noniterative systems) is shown in (19).

(19) *Iterative footing.*

a. FtBin È Parse-σ È Ft-Left
(σ σ)(σ σ)
(σ σ)(σ σ)σ
(Pintupi, Diyari)

b. Parse-σ È FtBin : Ft-Left
(σ σ)(σ σ)
(σ)(σ σ)(σ σ)
(Weri)

c. FtBin È Parse-σ È Ft-Right
(σ σ)(σ σ)
σ(σ σ)(σ σ)
(Yakan)

d. Parse-σ È FtBin : Ft-Right
(σ σ)(σ σ)
(σ σ)(σ σ)(σ)
(Ono, Icelandic)

One distinction between the OT analysis we present and a parametric approach is the degree of dependency predicted to hold between specific properties of metrical structures. Our analysis predicts no dependency between iterativity on the one hand and directionality and degeneracy on the other; switching the order of Parse-σ and Ft-Left (or Ft-Right) in a constraint hierarchy produces only a change in iterativity (this is not shown in (19)). Similarly, directionality can be varied independently of other properties by exchanging Ft-Left and Ft-Right, as long as the positions of Parse-σ and FtBin are held constant (compare (19a) and (19b) with (19c) and (19d), respectively). Exchanging the positions of Parse-σ and FtBin has more complicated consequences, however: in the specific cases where Parse-σ dominates Ft-Left or Ft-Right, directionality *and* the admissibility of degenerate feet co-vary depending on the position of FtBin with respect to Parse-σ. This means that the difference between Pintupi and Weri (or between Icelandic and Yakan) is as minimal as the difference between Pintupi and Yakan, or between Weri and Icelandic: each of these pairs is distinguished by a difference in the

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[9] As noted earlier in footnote 3, the constraint *Struc-Ft would play a role in our analysis if Parse-σ and Ft-left (or Ft-Right) could be shown to be unranked.

[10] For recent parametric theories, see Hayes (1981, 1987, 1994), Halle & Vergnaud (1987), Halle (1990), and Kager (1989), Hewitt (1992), and Idsardi (1992).

hierarchical order of only one pair of constraints. The difference between Weri and Yakan or between Pintupi and Icelandic, by contrast, is not minimal: these languages pairs differ in the hierarchical interaction of two pairs of constraints.

A parametric theory, by contrast, predicts that iterativity, directionality, and degeneracy are fully independent: no two of these properties should co-vary when the setting for a single parameter is changed. The relationship between degeneracy and directionality under the parametric view is illustrated below in a two-by-two display:

(20) *A parametric approach*

			Degeneracy ✓ $_F$(σ)		$*_F$(σ)
Directionality:	L-to-R	a.	(σ σ)(σ σ) (σ σ)(σ σ)(σ) (Ono, Icelandic)	b.	(σ σ)(σ σ) (σ σ)(σ σ)σ (Pintupi, Diyari)
	R-to-L	c.	(σ σ)(σ σ) (σ)(σ σ)(σ σ) (Weri)	d.	(σ σ)(σ σ) σ(σ σ)(σ σ) (Yakan)

The minimal contrasts in the above table are between the pairs (20a), (20c) and (20b), (20d), which contrast on direction of footing; and the pairs (20a), (20b) and (20c), (20d), distinguished by the presence vs. absence of degenerate feet. Contrasts between (20a) (20d), and between (20b) and (20c) are nonminimal, as these require changing two parameter settings.

Thus, the OT and parametric approaches predict different subsets of the metrical systems we have discussed to be minimally contrastive. The interesting similarities and differences are represented in (21). Of greatest interest is the observation that the OT and parametric approaches differ symmetrically in the contrasts they predict to be minimal vs. nonminimal. We assume that two OT grammars contrast minimally if they differ in the hierarchical order of a pair of local constraints (where *local* means adjacent in the sense that no third constraint crucially intervenes between them in the hierarchy).

(21) *Some predictions:*

	Minimal	*Nonminimal*
OT	a. (σ σ)(σ σ)σ ↔ σ(σ σ)(σ σ) Pintupi vs. Yakan b. (σ)(σ σ)(σ σ) ↔ (σ σ)(σ σ)(σ) Weri vs. Icelandic c. (σ σ)(σ σ)σ ↔ (σ)(σ σ)(σ σ) **Pintupi vs. Weri** d. (σ σ)(σ σ)(σ) ↔ σ(σ σ)(σ σ) **Icelandic vs. Yakan**	i. (σ σ)(σ σ)σ ↔ (σ σ)(σ σ)(σ) **Pintupi vs. Icelandic** j. (σ)(σ σ)(σ σ) ↔ σ(σ σ)(σ σ) **Weri vs. Yakan**
Parameter	e. (σ σ)(σ σ)σ ↔ σ(σ σ)(σ σ) Pintupi vs. Yakan f. (σ)(σ σ)(σ σ) ↔ (σ σ)(σ σ)(σ) Weri vs. Icelandic g. (σ σ)(σ σ)σ ↔ (σ σ)(σ σ)(σ) **Pintupi vs. Icelandic** h. (σ)(σ σ)(σ σ) ↔ σ(σ σ)(σ σ) **Weri vs. Yakan**	k. (σ σ)(σ σ)σ ↔ (σ)(σ σ)(σ σ) **Pintupi vs. Weri** l. (σ σ)(σ σ)(σ) ↔ σ(σ σ)(σ σ) **Icelandic vs. Yakan**

The different predictions of the parametric and OT views with respect to dependency have potential implications for language change and language-internal variation. Under the assumption that change creeps--rather than sweeps--across language, diachronically related stages of a language, as well as distinct systems coexisting synchronically within a language, should be distinguished by minimal rather than nonminimal contrasts. If the prediction of the parametric model that directionality and degeneracy may vary independently is correct, then we might expect the shifts in (21e,f) (by changing directionality) and (21g,h) (by relaxing a ban on degenerate feet) to be common, while (21k,l) should not be. However, exactly (21k,l) are predicted to be common under the OT account, whereas (21g,h) should not be.

An example of the shift in (21l), predicted under the OT but not the parametric account, is in fact attested synchronically in Cahuilla (Seiler 1965, 1970, 1977; Seiler & Hioki 1979; Levin 1988; Hayes 1994). In this language, stress is assigned bidirectionally, effected by reversing the direction of footing in different lexical domains. Within the domain of the stem and suffixes, stress alternates on odd-numbered morae from the left.[11] The stem-initial stress is primary. Final, odd-numbered syllables receive stress, showing that degenerate feet are permitted. Examples appear in (22). (Page references are to Seiler 1970, *Sa*, Seiler 1977, *Sb*, and Hayes 1994, *H*.)[12]

(22) *Cahuilla*

p•4ax	(p•4ax)	'from far' Sa30
p‡?l“	(p‡?)(l“)	'the water (obj.)' Sb28/H133
s’l^{y}eqˆl	(s’l^{y}e)(qˆl)	'flow-past' Sa12/79
'•k^{w}asmˆ'lih	('•k^{w}as)(mˆ'lih)	'boy-loc.' Sa12/125

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11 In moraic systems, two light syllables and one heavy syllable are metrically equivalent. In Cahuilla, syllables with long vowels or diphthongs, and syllables closed by a glottal stop count as heavy.

12 The Cahuilla facts are somewhat more complex than this. A point of interest concerns the fate of light syllables "trapped" between either a foot or a domain edge and an adjacent heavy syllable, which must on its own form a foot. Examples currently available to us involve word-initial light syllables which consistently receive stress (e.g. *pen#p•n“:\Q(c,ÿ)“niqˆ*, *pen#(p•)(n“:)(\Q(c,ÿ)“ni)(qˆ)* 'translate' Seiler & Hioki 1979:148/H135). An alternate pronunciation exists in which the medial stress fails to surface (e.g. *pen#p•ni:\Q(c,ÿ)“niqˆ*) showing that longer strings of stressed syllables are unstable. The important point for present purposes is that degenerate feet are possible under the analysis we provide. Furthermore, the presence of degenerate feet in non-final positions under the ranking Parse-σ È FtBin È Ft-Left is expected in quantity-sensitive systems (readers may verify this by constructing relevant tableaux). Hayes (1994) claims that final stresses in Cahuilla are a phonetic artefact and have no phonological representation, and that initial degenerate feet are tolerated only because they bear main stress. Our analysis predicts degenerate feet both initially and finally under the right circumstances, and also medially in strings like (LL)(L)(H), though we cannot at present provide examples. For a more detailed account of Cahuilla stress, see especially Hayes (1994).

q‡:nk“\O(c,ÿ)em (q‡:n)(k“\O(c,ÿ)em) 'palo verde (pl.)' Sb27/H133

P‡tsaqˆraw“h (P‡tsa)(qˆra)(w“h) 'name' Sa113

When prefixes are added, stress falls on even numbered morae counting backward from the stem, but not on initial odd-numbered light syllables. In other words, no degenerate feet are possible within the prefix string. The resulting effect of bidirectional footing is illustrated in (23) (# separates a stem and prefixes; page numbers with *L* refer to Levin 1988; those with *Sc* are to Seiler 1965).

(23) *Bidirectional footing in Cahuilla*

ne#yœl ne#(yœl) 'my younger brother' Sb33/H133

pˆpen#tœleqˆlev•h (pˆpen)#(tœle)(qˆle)(v•h) 'where I was grinding it' Sc52/H133

taxh•m\Ọ(c,ÿ)em#‡qinw•n tax(h•m\Ọ(c,ÿ)em)#(‡qin)(w•n) (no gloss) Sa149/L341

pˆ:mt•va#x‡wen (pˆ:m)(t•va)#(x‡wen) (no gloss) Sa61/L341

Our analysis of Cahuilla is summarized in (24):[13]

(24) *Cahuilla stress*

a. Stem plus suffix domain: Parse-σ È FtBin : Ft-Right
(or ...FtBin È Ft-Right)

b. Prefix domain: FtBin È Parse-σ È Ft-Right

Regardless of whether Cahuilla's stress system was once uniformly Parse-σ È FtBin : Ft-Right[14] or FtBin È Parse-σ È Ft-Right, an exchange in the positions of Parse-σ and FtBin would leave Parse-σ dominating Ft-Right, with the desired results.[15] Both hierarchies would need to coexist in the language, but hold for different lexical domains. Under either alternative, only a single reranking is required, by contrast with the parametric model, in which two parameters would need to be reset. An example of a two-change shift under our analysis would be a right-to-left language which begins with no degenerate feet but later permits them, or vice versa. Such a change would require reranking not only FtBin and Parse-σ, but also Ft-Left and Ft-right. To the extent that shifts of this kind are common in languages (while shifts like (21i) or (21j) are not), the optimality-theoretic analysis should be preferred over the parametric approach.

3. Conclusion

In this paper, we have shown that an uncontroversial OT analysis of iterative and noniterative metrical footing has implications which have not been considered in earlier work. Quite simply, this analysis predicts that direction of footing effects in iterative stress systems are dependent on the presence vs. absence of degenerate feet. When Ft-Left outranks Ft-Right and left-to-right directional effects are apparent, representations should contain no sub-binary feet, an effect of FtBin dominance. The co-occurrence of these properties emerges under the constraint hierarchy FtBin È Parse-σ È Ft-Left. On the other hand, right-to-left effects are predicted to appear with degenerate feet under the hierarchy Parse-σ È FtBin : Ft-Left. When Ft-right exchanges positions with Ft-Left in the above hierarchies, the mirror image patterns emerge: under the hierarchy FtBin È

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13 A parametric analysis of Cahuilla must include the following elements:
Prefix: Moraic trochees, right-to-left, *degenerate-foot
Stem/suffix: Moraic trochees, left-to-right, ✓ degenerate feet

14 ...or Parse-σ È FtBin È Ft-Right, or Parse-σ È Ft-Right È FtBin; recall that ranking between FtBin and Ft-Right is not critical.

15 It is interesting that the net outcome is that the left edge of the root morpheme is doubly aligned (on the left and the right) with a foot. Such foot/root relations might have been factors in the difference discussed here.

Parse-σ È Ft-Right, leftward footing effects are accompanied by an absence of degenerate feet; when rightward effects appear under Parse-σ È FtBin : Ft-Right so do sub-binary feet. The dependency between direction of footing and degeneracy predicted under the OT analysis is not predicted by theories which derive metrical structures by varying settings for a number of autonomous parameters.

We have noted that the contrasting predictions of the OT and parametric models with respect to dependency have different implications for language change, under the assumption that diachronically or synchronically related grammars are more likely to be distinguished by minimal than by nonminimal contrasts. Minimal and nonminimal contrasts predicted under OT and parametric approaches are identified in (21).

In practice, we cannot make the na•ve assumption that all (and only) the minimal contrasts predicted under either account should be reflected with equal frequency in language change. Some shifts predicted to occur on grounds of simplicity under our view might be impeded through the influence of constraints not considered in this paper. Conversely, other changes we predict to be infrequent might in fact be favoured by another constraint. As an example, the shift from a \O(σ,ó) σ \O(σ,ó) σ σ to a \O(σ,ó) σ \O(σ,ó) σ \O(σ,ó) system, disfavoured under our account if only the constraints FtBin, Parse-σ, and Ft-Left are considered, might conceivably be forced by a requirement that final syllables be phonetically stressed, though no foot structure may be present (an alternative to degenerate feet promoted in Hayes 1994). On the other hand, although we predict shifts from systems like (σ σ)(σ σ)σ to ones like (σ)(σ σ)(σ σ), these are likely to be uncommon in actuality, due to the universal markedness of degenerate feet. A full and satisfying treatment of these issues requires a more complete understanding of constraints, crosslinguistically marked and unmarked metrical patterns, and the proper treatment of markedness issues in a constraint-based phonology than we presently have available. We leave these issues to be resolved in future research.

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