Generalized alignment and morphological parsing

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1. Introduction

In this paper I will consider the robustness of linguistic interpretation by focussing on the rôle of word-level prosody in the overdetermination of morphological structure. A property of many stress languages which has been recognized at least as early as Trubetzkoy (1939) is that stress tends to fall close to edges of words or stems. Czech, for example, has strict initial word-stress, whereas Indonesian has strict penultimate word-stress. This is the so-called *demarcative* property of word-stress. Upon the traditional view, stress at edges of morphemes functions as a signal for morphemes, and thus facilitates the morphological processing. One might then say that word stress *over-determines* morphological structure, and contributes to the robustness of the grammar. From a psycholinguistic perspective, the functional view has been corroborated by experimental work by Cutler and Norris (1988), which shows that edge portions of words carry a high functional load in word-recognition, stressed syllables in the word onset being specially relevant. In this contribution I wish to focus on the grammatical principles which underlie the demarcative property of word-stress, and their interaction with other principles of grammar.

In standard rule-based metrical phonology, stresses at edges of words are produced in a fairly indirect fashion, by a conspiracy of mutually independent rules and principles. These include directional construction of metrical feet in a morphological domain, the selection of one of these as the main stress foot, as well as stress deletion to repair particular outputs of foot construction. Still, capturing a linguistic generalization through a rule conspiracy essentially reduces it to an accidental constellation of factors instead of expressing it directly. Note in particular that rule-based metrical theory fails to explain the fact that demarcative stress conspiracies show up in many languages, since the ingredients of the analyses are predicted to be cross-linguistically independent. To put it differently, conspiracies have little if any explanatory force, nor do they contribute to an explanation of robustness.

In an attempt to overcome these problems, McCarthy and Prince (1993a,b) have argued that alignments between feet and morphological edges should be expressed directly in universal grammar. Elaborating on the edge-based theory of the syntax-phonology interface of Selkirk (1986), Cohn (1989), and others, McCarthy and Prince express alignment in the general constraint format of *Generalized Alignment* (GA):

(1) **Generalized Alignment**

Align (Cat_1, $Edge_1$, Cat_2, $Edge_2$) $=_{def}$

$\forall$ Cat_1 $\exists$ Cat_2 such that $Edge_1$ of Cat_1 and $Edge_2$ of Cat_2 coincide.

Where Cat_1, $Cat_2 \in$ ProsCat $\cup$ GramCat

$Edge_1$, $Edge_2 \in$ {Right, Left}

GramCat consists of morphological categories (*Word*, *Stem*, *Affix*, *Root*, etc.), while ProsCat consists of prosodic categories (*Mora*, *Syllable*, *Foot*, *Prosodic Word*, etc.). The notion of 'coinciding edges' is further formalized in the McCarthy and Prince paper. Crucially, quantification of Cat_1 is *universal* whereas that of Cat_2 is *existential* ("for each Cat_1 there is some Cat_2 ..."). Accordingly, the two alignments constraints below have different interpretations:

(2) a. ALIGN-WD-L: Align (PrWd, Left, Foot, Left)

b. ALL-FT-L: Align (Foot, Left, PrWd, Left)

Constraint (2a) states that for each left PrWd edge there is some left foot edge which coincides with it. It is violated by each PrWd which does not begin with a foot. Constraint (2a) states that for each left foot edge, there is some left PrWd edge which coincides with it. It is violated by each foot which does not lie at the beginning of a PrWd. Such differences become important in structures which contain multiple feet, or multiple PrWds.

McCarthy and Prince implement Generalized Alignment in the framework of *Optimality Theory* (Prince and Smolensky 1993). In this theory, there are no derivations by ordered rules, but only well-formedness constraints which evaluate possible output representations. Well-formedness of outputs is taken to be a relative notion. The output selected by the grammar is the one which violates the smallest number of constraints. Crucially, constraints are ranked hierarchically in a language-specific manner, so that lower-ranking constraints may be violated in order to satisfy higher-ranking constraints. All constraints are universal, as well as violable.

Initial main stress in Czech is due to undominated ALIGN-WD-L aligning the left PrWd edge with a left foot edge (3a). Likewise, penultimate main stress in Indonesian is due to ALIGN-WD-R aligning the right PrWd edge with a right foot edge (3b).

(3) a. ALIGN-WD-L: Align (PrWd, Left, Foot, Left)

b. ALIGN-WD-R: Align (PrWd, Right, Foot, Right)

Optimality Theory predicts that Generalized Alignment interacts with other constraints, depending on its relative ranking. One expects to find grammars in which an alignment constraint is high-ranked, but can nevertheless be violated in order to satisfy top-ranking constraints, such as foot well-formedness, and avoidance of adjacent stresses. But the same alignment constraint may still be active in selecting the optimal output in cases in which higher-ranking constraints make no decision.

A typical example of constraint interaction can be found in languages in which alignment ranks below *Foot Binarity*. FT-BIN says that metrical feet, the rhythmic units of stress, are analyseable as either two syllables or two moras (McCarthy and Prince 1986, 1993a,b, Hayes 1994, Kager 1989, 1993). An example of this interaction between alignment and FT-BIN occurs in languages such as Polish, Indonesian, Piro, and Sibutu Sama, discussed in section 2. These languages have main stress on the pre-final (penultimate) syllable of the word, and a secondary stress on the word-initial syllable, e.g. Sibutu Sama *bìssaláhan* 'persuading'. This pattern signals ALIGN-WD-R (with respect to the main stress foot) in combination with ALIGN-WD-L (with respect to the initial secondary stress foot). Typically, trisyllabic words in such languages lack the initial secondary stress, having only main stress on the penultimate syllable, e.g. Sibutu Sama *bissála* 'talk' (instead of **bìssála*). This familiar pattern is due to an ordering of constraints in which FT-BIN takes top-priority, followed by ALIGN-WD-R and ALIGN-WD-L, in that order. In trisyllabic words satisfaction of FT-BIN goes at the expense of ALIGN-WD-L.

Three possible metrical structures of the trisyllabic word example from Sibutu Sama are represented in (4). Trochaic feet, rhythmic units which consist of a strong and a weak syllable, are represented above the syllable level, the strong syllable by a star, and the weak syllable by a dot. Feet themselves are organized by a higher-level prosodic unit, the Prosodic Word. A star at this level indicates the main stress, the strongest syllable in the word. ALIGN-WD-R is satisfied by both (4a) and (4b), but not by (4c). ALIGN-WD-L is satisfied by both (4a) and (4c), but not by (4b). Note that the single candidate structure that satisfies both ALIGN-WD-R and ALIGN-WD-L is (4a), but this violates undominated FT-BIN, because of its initial monosyllabic foot. Of the two remaining structures that satisfy FT-BIN the grammar selects (4b) over (4c), since satisfaction of ALIGN-WD-R takes priority over satisfaction of ALIGN-WD-L:

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(4)  a.   (    *   )      b.   (.   *   )      c.   (*       )
          (*)(*  .)              .  (*  .)          (*    .) .
           σ   σ σ              σ   σ σ             σ   σ σ
          *bìssála             bissála            *bíssala
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In this paper, I will explore the consequences of this theory of prosodic alignment on the basis of four languages: Sibutu Sama, Diyari, Dyirbal, and Walpiri. I hope to show that alignment principles, in the context of constraint interaction in Optimality Theory, form an insightful formalization of the demarcative property of word stress. In this sense alignment contributes to an explanation of the robustness of linguistic interpretation.

2. Sibutu Sama

Sibutu Sama is an Austronesian language of the Southern Philippines (Allison 1979). It has strict penultimate main stress, but displays an interesting sensitivity to morphological structure in long prefixed words. As shown in (5b-d), unprefixed words have an initial secondary stress, unless the main stress immediately follows, as in (5a).

(5)	a.	bissála	'talk'
	b.	bìssalá-han	'persuading'
	c.	bìssala-hán-na	'he is persuading'
	d.	bìssala-han-kámi	'we are persuading'

The stress pattern diagnoses trochaic feet, rhythmic units whose initial syllable is strong, and whose second syllable is weak. One trochee, which has the main stress, parses the two syllables at word end. Another trochee, at word beginning, has secondary stress. We have already seen the basic constraint interaction responsible for (5a) in section 1 (example 4).

The secondary stress pattern of prefixed words is somewhat more complex than that of unprefixed words. Words which have one or more disyllabic prefixes have a secondary stress on each initial prefix syllable, as well as a secondary stress on the first stem syllable. In (6a), no secondary stress occurs on the stem-initial syllable, which again follows from FT-BIN.

(6)	a.	màka-bissála	'able to talk'
	b.	pìna-bìssalá-han	'to be persuaded'
	c.	màka-pàgba-bissalá-han[1]	'able to cause persuasion'

Two monosyllabic prefixes act together as a single disyllabic prefix. That is, a secondary stress falls on the first prefix, and another on the first stem syllable:

(7)	a.	kà-pag-bissála	'able to talk to each other'
	b.	tà-pag-bìssalá-han	'the thing able to be spoken about'

In words which have only one monosyllabic prefix, the secondary stress fluctuates. It falls either on the monosyllabic prefix or on the stem-initial syllable.

(8) a. pà-missalá-han *or* pa-mìssalá-han
‘instrument for speaking’
b. pàg-bissalá-han *or* pag-bìssalá-han
‘the thing spoken about’

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[1] Allison claims that words with two disyllabic prefixes have no stem-initial stress, something for which I can provide no explanation.

Words which have a disyllabic prefix followed by a monosyllabic prefix display a similar fluctuation. These carry an initial secondary stress on the disyllabic prefix, and another secondary stress which falls either on the monosyllabic prefix, or on the first syllable of the stem.

(9) a. màka-pag-bìssalá-han *or* màka-pàg-bissalá-han
'able to persuade them'
b. tàpag-pa-bìssala-hán-bi *or* tàpag-pà-bissala-hán-bi
'you (pl.) are able to make them persuade someone'

We observe a preference for both prefix and stem edges to be marked by an initial secondary stress. The challenge is how to account for the fluctuation observed in some forms vs. the fixed pattern in others. My analysis of Sibutu Sama has three undominated constraints (10a-c) which produce fixed penultimate main stress: FT-BIN, TROCH-FT, and ALIGN-WD-R. Two alignment constraints rank below these. ALIGN-ST-L (10d) aligns left stem edges with left foot edges. This constraint is responsible for initial stress in stems and prefixes. To make sure that it actually has this effect I define the morphological stem as a recursive category (McCarthy and Prince 1993b). By recursive definition, the notion of *left stem edge* comes to include every left prefix edge. Root edges are simply the innermost stem edges. ALL-FT-L (10e) aligns left edges of feet with the left PrWd edge. I assume the interpretation of McCarthy and Prince (1993b), by which violations of this constraint are counted per foot, by number of syllables from the specified edge. Since all feet which do not lie at the left PrWd edge induce violations, this minimizes the number of feet. Its main function is to rule out medial feet in long unprefixed stems such as (5d), but we will see below that it has another function. Finally, ALIGN-RT-L (10f) aligns left root edges with left foot edges. Its function (apart from ALIGN-ST-L) will become clear when we discuss fluctuating secondary stress, and will find that it is ranked equally with ALL-FT-L. The grammar of Sibutu Sama stress can now be stated as a set of ranked constraints in (10):

(10) a. FT-BIN: Feet are disyllabic.
b. TROCH-FT: Feet are trochees.
c. ALIGN-WD-R: Align (PrWd, Right, Main stress foot, Right).
d. ALIGN-ST-L: Align (Stem, Left, Foot, Left)
e. ALL-FT-L: Align (Foot, Left, PrWd, Left)
f. ALIGN-RO-L: Align (Root, Left, Foot, Left)

First consider the simplest cases in which ALIGN-WD-R suffices to select the correct output. I follow the notational conventions for the evaluation of outputs, in the form of tableaux (Prince and Smolensky 1993). A constraint violation is indicated by "*", a fatal violation by "!", and the optimal output by "☞". I indicate foot brackets by parentheses "(", ")", PrWd edges by "[", "]", left stem edges by "-", and root edges by "=". Suffix edges will not be indicated.

(11) /bissala/	FT-BIN	TROCH-FT	ALIGN-WD-R	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i. ☞ [bis.(sá.la)]				*	bis	*
ii. [(bís.sa).la]			* !			
iii. [bis.(sa.lá)]		* !		*	bis	*
iv. [(bìs).(sá.la)]	* !				bis	*

The correct output is selected by FT-BIN, TROCH-FT, and ALIGN-WD-R. Observe that ALIGN-ST-L is violated in the optimal output candidate (11a), in order to satisfy the two higher-ranking constraints.

Next consider cases for which ALIGN-ST-L suffices to select the correct output: long unprefixed words, and words with only disyllabic prefixes. I do not consider outputs violating undominated FT-BIN, TROCH-FT or ALIGN-WD-R. I will not indicate violations of ALL-FT-L induced by the main stress foot, as this in in the same position in all output candidates to be considered.

(12a) /bissalahan/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i. ☞ [(bìs.sa).(lá.han)]			
ii. [bis.sa.(lá.han)]	* !		*

(12b) /bissalahanna/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i. ☞ [(bìs.sa).la.(hán.na)]			
ii. [bis.sa.la.(hán.na)]	* !		*

(12c) / pina=bissalahan/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i. ☞ [(pì.na)=(bìs.sa).(lá.han)]		pi.na	
ii. [(pì.na)=bis.sa.(lá.han)]	* !		*
iii. [pi.na=(bìs.sa).(lá.han)]	* !	pi.na	
iv. [pi.(nà=bis).sa.(lá.han)]	* ! *	pi	*
v. [pi.na=bis.sa.(lá.han)]	* ! *		*

(12d) /maka-pagba=bissalahan/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i. ☞ [(mà.ka)-(pàg.ba)=(bìs.sa).(lá.han)]		ma.ka, ma.ka.pag.ba	
ii. [(mà.ka)-pag.ba=(bìs.sa).(lá.han)]	* !	ma.ka.pag.ba	
iii. [(mà.ka)-pag.(bà=bis).sa.(lá.han)]	* ! *	ma.ka.pag	*
iv. [(mà.ka)-pag.ba=bis.sa.(lá.han)]	* ! *		*
v. [ma.ka-pag.ba=(bìs.sa).(lá.han)]	* ! *	ma.ka.pag.ba	
vi. [ma.(kà-pag).ba=(bìs.sa).(lá.han)]	* ! *	ma, ma.ka.pag.ba	

In the second group of cases, those of (13), ALIGN-ST-L is necessarily violated in order to satisfy the higher-ranking constraints (in particular FT-BIN). This is because these words contain either monosyllabic prefixes or a trisyllabic stem. Here the optimal output is the one which minimally violates ALIGN-ST-L. (Prince and Smolensky 1993 call this *multiple gradient violation*.)

(13a)	/maka=bissala/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i.	☞ [(mà.ka)=bis.(sá.la)]	*		*
ii.	[ma.(kà=bis).(sá.la)]	** !	ma	*
iii.	[ma.ka=bis.(sá.la)]	** !		*

(13b)	/ta-pag=bissalahan/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i.	☞ [(tà-pag)=(bìs.sa).(lá.han)]	*	ta.pag	
ii.	[(tà-pag)=bis.sa.(lá.han)]	** !		*
iii.	[ta-(pàg=bis).sa.(lá.han)]	** !	ta	
iv.	[ta-pag=(bìs.sa).(lá.han)]	** !	ta.pag	
v.	[ta-pag=bis.sa.(lá.han)]	** !		*

Observe how this analysis naturally groups together the case of a single disyllabic prefix (13a) with that of two monosyllabic prefixes (13b).

The function of ALL-FT-L becomes clear when we consider unprefixed long words, and a class of words with two monosyllabic prefixes. As said above, McCarthy and Prince (1993b) count violations of ALL-FT-L per foot, by numbers of syllables from the left PrWd edge. I do not count the main stress foot for the purposes of this constraint, its position being fixed by the undominated constraint ALIGN-WD-R, which is necessarily violated to the same extent by all candidates corresponding to a single input. Note that in the third form of (14a), the fatal violation arises by the medial foot (*là-han*), not by the initial foot (*bìssa*), which perfectly aligns with the left PrWd edge:

(14a)	/bissalahankami/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i.	☞ [(bìs.sa).la.han.(ká.mi)]			
ii.	[(bìs.sa).(là.han).(ká.mi)]		bis.sa !	
iii.	[bis.(sà.la).han.(ká.mi)]	* !	bis	*
iv.	[bis.sa.la.han.(ká.mi)]	* !		*

(14b)	/ka-pag=bissala/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i.	☞ [(kà-pag)=bis.(sá.la)]	**		*
ii.	[ka-(pàg=bis).(sá.la)]	**	ka !	*
iii.	[ka-pag=bis.(sá.la)]	*** !		*

ALL-FT-L rules out multiple secondary stresses in (14a.ii). In (14b), ALIGN-ST-L is necessarily violated in all outputs, because of FT-BIN. The outputs (14b.i-ii) have an equal number of violations of ALIGN-ST-L. ALL-FT-L then steps in, selecting the output in which the secondary stress foot lies as near to the left PrWd edge as possible.

Finally consider the cases of fluctuating secondary stress. In Optimality Theory cases of fluctuating outputs can be handled by a *tie* of constraints. When two constraints C_1 and C_2 are ranked equally, the evaluation procedure branches at that point. In one branch, constraint C_1 is ranked above constraint C_2, while in the other branch, the ranking is reversed. Sibutu Sama has a tie of two constraints ALL-FT-L and ALIGN-RO-L. In the branch where ALL-FT-L ranks higher, word-initial secondary stress is optimal (cf. 15a); while in the other branch, where ALIGN-RO-L ranks higher, a root-initial secondary is optimal (cf. 15b):

(15a)	/pa=missalahan/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i.	☞ [(pà=mis).sa.(lá.han)]	*		*
ii.	[pa=(mìs.sa).(lá.han)]	*	pa !	
iii.	[pa=mis.sa.(lá.han)]	** !		*

(15b)	/pa=missalahan/	ALIGN-ST-L	ALIGN-RO-L	ALL-FT-L
i.	☞ [pa=(mìs.sa).(lá.han)]	*		pa
ii.	[(pà=mis).sa.(lá.han)]	*	* !	
iii.	[pa=mis.sa.(lá.han)]	** !		*

The branching tableaux for *maka-pag=bissalahan* works likewise:

(16a)	/maka-pag=bissalahan/	ALIGN-ST-L	ALL-FT-L	ALIGN-RO-L
i.	☞ [(mà.ka)-(pàg=bis).sa.(lá.han)]	*	ma.ka	*
ii.	[(mà.ka)-pag=(bìs.sa).(lá.han)]	*	pa.ka.pag !	
iii.	[(mà.ka)-pag=bis.sa.(lá.han)]	** !		*
iv.	[ma.ka-pag=(bìs.sa).(lá.han)]	** !	ma.ka.pag	
v.	[ma.(kà-pag)=(bìs.sa).(lá.han)]	** !	ma, ma.ka.pag	
vi.	[ma.ka-pag=bis.sa.(lá.han)]	** ! *		*

(16b)	/maka-pag=bissalahan/	ALIGN-ST-L	ALIGN-RO-L	ALL-FT-L
i.	☞ [(mà.ka)-pag=(bìs.sa).(lá.han)]	*		ma.ka.pag
ii.	[(mà.ka)-(pàg=bis).sa.(lá.han)]	*	* !	ma.ka
iii.	[ma.ka-pag=(bìs.sa).(lá.han)]	** !		ma.ka.pag
iv.	[ma.(kà-pag)=(bìs.sa).(lá.han)]	** !		ma, ma.ka.pag
v.	[(mà.ka)-pag=bis.sa.(lá.han)]	** !	*	
vi.	[ma.ka-pag=bis.sa.(lá.han)]	** ! *	*	

Let us now see how rule-based metrical theory would handle this stress pattern. First, a syllabic trochee is built at the right edge of PrWd, which receives main stress by End Rule Final. Second, a single syllabic trochee is built on the left edge of the stem. The fact that prefixed words can have multiple secondary stresses (in contrast to unprefixed words) may be analysed by cyclic foot construction, each prefix triggering a new cycle (while suffixes do not). On each cycle a single syllabic trochee is constructed at the left edge of the domain. This accounts for words with disyllabic prefixes.

As to words with monosyllabic prefixes the problem is how to account for the fluctuation of secondary stress. A standard rule-based metrical analysis would set up monosyllabic feet in intermediary representations, and then resolve stress clashes by a de-stressing rule. Although clash resolution itself is obligatory, the choice of the syllable to be de-stressed would be left unspecified. Let us assume that de-stressing takes place non-cyclically, at a level of the derivation where all stems and prefixes have initial stresses by cyclic foot construction. Below, the vowels of the syllables which are optionally de-stressed have been underlined. Those which are obligatorily de-stressed have been doubly underlined.

```
(17)  a.  (          *   )             b.  (            *   )
          (*)(* .)(* .)                    (*)(*) (*)(* .)
          pa-missaláhan                    ka-pag=bissála

      c.  (              *   )         d.  (                *   )
          (*)(*) (* .)(* .)                (* .)(*) (* .)(* .)
          ta-pag=bissaláhan                maka-pag=bissaláhan
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Next consider the application of destressing. First, secondary stresses adjacent to the main stress are removed (producing /*kà-pàg=bissála*/, 17b.), assuming the *Trigger-Prominence-Principle* of Hammond (1988). Second, if the output still contains adjacent stresses, destressing removes either of the stresses involved in the clash. At this point, the problem is how to distinguish /*pà=mìssaláhan*/ (17a) from /*kà-pàg=bissála*/ (17b). Both have stresses on the first and second syllables. In the former example, either the first or the second syllable can be de-stressed ([*pà=missaláhan*] or [*pa=mìssaláhan*]). But in the latter example only the second syllable can be destressed ([*kà-pag=bissála*], *[*ka-pàg=bissála*]). There is no obvious solution to this problem.

This problem set aside, a rule-based analysis misses two generalizations. First, foot binarity is only indirectly accounted for by a conspiracy of rules. Monosyllabic feet are set up at intermediary levels of the derivation, after which stress clashes are resolved by destressing. Second, both cyclic foot construction and destressing independently refer to left morpheme edges. The analysis therefore misses the generalization that morpheme edges are maximally signalled by stresses. The constraint-based analysis captures both generalizations by FT-BIN and ALIGN-ST/RO-L, respectively.

3. Diyari

I now turn to three Australian languages, Diyari, Dyirbal, and Warlpiri, which all display stress alignment properties in the root plus suffix complex. All have initial stress, and alternating stress in the rest of the word. However, the languages differ interestingly in suffix 'coherence', the extent to which foot parsing is allowed to cross morpheme edges. Polysyllabic suffixes behave differently from monosyllabic suffixes, while roots behave differently from suffixes.

Diyari is a Pama-Nyungan language of South Australia (Austin 1981). Primary stress falls on the first syllable of a root. Secondary stress falls on the first syllable of a polysyllabic suffix and on the third syllable of a four syllable morpheme. See the examples in (19):

(19)	a.	2	kána	'man'
	b.	3	pínadu	'old man'
	c.	4	wílapìna	'old woman'
	d.	2+1	kána-ni	'man-LOC'
	e.	3+1	púluru-ngi	'mud-LOC'
	f.	2+2	kána-wàra	'man-PL'
	g.	3+2	pínadu-wàra	'old man-PL'
	h.	4+2	wílapìna-wàra	'old woman-PL'
	i.	2+4	táyi-yàtimàyi	'to eat-OPT'
	j.	2+1+1	máda-la-ntu	'hill-CHARAC-PROPR'
	k.	2+1+2	kána-ni-màta	'man-LOC-IDENT'
	l.	2+2+1	kána-wàra-ngu	'man-PL-LOC'
	m.	3+2+2+1	kána-wàra-ngùndu	'man-PL-ABL'
	n.	3+2+2+1	yákalka-yìrpa-màli-na	'to ask-BEN-RECIP-PART'

McCarthy and Prince (1994) show that the 'monosyllable' effect is due to a complete alignment between Stem and PrWd, both taken as recursive categories. That is, the PrWd is self-embedding, copying the recursive structure *Stem -> Stem Af*, which is marked by curly brackets:

(20)		*Morphological structure*	*PrWd structure*
	a.	{{{mada}-la}-ntu}	[[[mada]-la]-ntu]
	b.	{{puluru}-ngi}	[[puluru]-ngi]
	c.	{{pinadu}-wara}	[[pinadu]-wara]
	d.	{{{kana}-ni}-mata}	[[[kana]-ni]-mata]

This 'Stem-recursion' effect results from ranking two constraints at the top of the hierarchy (see Orgun to appear, Crowhurst to appear for slightly different analyses):

(21)	a.	ALIGN-ST-R:	Align (Stem, Right, PrWd, Right)
	b.	ALIGN-ST-L:	Align (Stem, Left, PrWd, Left)

Together these constraints have the effect that every Stem edge coindides with a PrWd edge. Observe that the crucial constraint of the pair of (21) blocking rightward alternating stress across morpheme boundaries is ALIGN-ST-R. ALIGN-ST-L plays no crucial rôle for stress, producing stacks of left PrWd boundaries at the word beginning. For expository reasons I will collapse ALIGN-ST-L/R into a single constraint ALIGN-ST.

To obtain the effect of chained left-edge-oriented feet in long morphemes, feet are left-aligned within PrWd, with PARSE-SYLL dominating ALL-FT-L:

(22)	a.	FT-BIN:	Feet are disyllabic trochees.
	b.	ALIGN-ST:	Align (Stem, Left/Right, PrWd, Left/Right).
	c.	PARSE-SYLL:	Every syllable belongs to a foot.
	d.	ALL-FT-L:	Align (Foot, Left, PrWd, Left)

Let us first consider the tableaux of some forms. As in Sibutu Sama, I do not consider outputs which violate FT-BIN. Note the similarity between (23a-b) and between (23c-d):

(23a) / {{{mada}-la}-ntu}/	ALIGN-ST	PARSE-SYLL	ALL-FT-L
i. ☞ [[[(má.da)]-la]-ntu]		**	
ii. [[(má.da)]-(là-ntu)]	* !		ma.da

(23b) / {{puluru}-ngi}/	ALIGN-ST	PARSE-SYLL	ALL-FT-L
i. ☞ [[(pú.lu).ru]-ngi]		**	
ii. [(pú.lu).(rù-ngi)]	* !		pu.lu

(23c) / {{pinadu}-wara}/	ALIGN-ST	PARSE-SYLL	ALL-FT-L
i. ☞ [[(pí.na).du]-(wà.ra)]		*	pi.na.du
ii. [[(pí.na).du]-wa.ra]		** ! *	
iii. [(pí.na).(dù-wa).ra]	* !	*	pi.na

(23d) / {{{kana}-ni}-mata}/	ALIGN-ST	PARSE-SYLL	ALL-FT-L
i. ☞ [[[(ká.na)]-ni]-(mà.ta)]		*	ka.na.ni
ii. [[[(ká.na)]-ni]-ma.ta]		** ! *	
iii. [[(ká.na)]-(ní-ma).ta)]	* !	*	ka.na

The virtues of this analyis are clear. The 'monosyllable' effect is a direct consequence of the dominance of Alignment. Each polysyllabic suffix begins with a stressed syllable, since feet in general are left-edge-oriented, and PARSE-SYLL dominates the foot-alignment constraint.

Let us now compare this optimization analysis of Diyari stress with a rule-based metrical analysis. In the literature several analysis have been proposed, all of which use directional footing. The first analysis, due to Poser (1989), uses cyclic foot construction from left to right. Monosyllabic feet are constructed so as to mark off the end of each cyclic domain (cf. 24ab). At the end of the derivation, all monosyllabic feet fall victim to *Monosyllabic Destressing* (cf. 24c).

(24)	a.	(*)	b.	(*)	c.	(*)
	First	(* .)(*)	Second	(* .)(*)(* .)	Mono.	(* .) . (* .)
	cycle	[pína du]	cycle	[pína dù wàra]	Destr.	[pína du wàra]

The problem with this analysis is that it uses monosyllabic feet in the first place. The minimal word of Diyari is disyllabic, and at the surface no monosyllabic feet appear. Therefore using monosyllabic feet at intermediate stages of the derivation makes this analysis highly abstract[2].

A non-cyclic variant on this analysis, due to Halle and Vergnaud (1987), assumes that each morpheme constitutes a stress domain on its own. Foot construction is rightward within a stress domain. As in Poser's analysis, there is complete destressing of monosyllabic feet[3].

(26)					(*)		
	(* .)	(*)	(* .)		(* .)	.	(* .)
	[kána]	[ní]	[máta]	=>	[kána]	[ni]	[máta]

Observe that monosyllabic morphemes are footed by monosyllabic feet, since by definition each stress domain must have a stressed syllable. Again, this assumption incorrectly predicts that Diyari has monosyllabic words.

4. Dyirbal

Dyirbal is a Pama-Nyungan language spoken in North Queensland, Australia (Dixon 1972). Its stress pattern differs from the Diyari pattern as follows. While root-final syllables are always unstressed as in Diyari, sequences of suffixes display an alternating stress pattern, starting on the first syllable of a sequence of suffixes (28c-g). Alternating stress ignores the difference between monosyllabic and polysyllabic suffixes (28f-g):

---

2 A variation on this cyclic analysis, due to Steriade (1988), and slightly revised by Hewitt (1992), avoids monosyllabic feet, but instead assumes that Stray Syllable Adjunction (SSA) applies cyclically to adjoin leftward any stray syllables left over at the end of the domain. The assumption that SSA is a cyclic rule radically contrasts with the standard view of SSA as an automatic principle applying at the end of the word level derivation, however.

3 Halle and Kenstowicz (1991) and Idsardi (1992) modify this analysis such that a left foot bracket is inserted at each morpheme boundary.

(28)	a.	2+1	wáynydyi-nyu	'motion uphill-REL.CL.'
	b.	3+1	búrgurrum-bu	'jumping ant-ERG'
	c.	2+1+1	wáynydyi-ngú-gu	'motion uphill-REL.CL.-DAT'
	d.	2+1+1+1	nyínay-má-riy-ma-n	'sit-COM-REFL-COM-P/P'
	e.	3+1+1+1	bánagay-mbá-ri-nyu	'return-REFL-COM-PRES/PAST'
	f.	2+1+2	dyángga-ná-mbila	'eat-PRON-with'
	g.	3+1+2	bánagay-ná-mbila	'return-PRON-with'

While alternating stress in Diyari may not cross right Stem boundaries, alternating stress in Dyirbal respects the right root boundary, but is free to cross any other right morpheme boundary. In (29), curly brackets indicate root edges:

(29)		*Morphological structure*	*PrWd structure*
	a.	{burgurrum}-bu	[[burgurrum]-bu]
	b.	{waynydyi}-ngu-gu	[[waynydyi]-ngu-gu]
	c.	{banagay}-mba-ri-nyu	[[banagay]-mba-ri-nyu]
	d.	{banagay}-na-mbila	[[banagay]-na-mbila]

PrWd parsings are due to a pair of alignment constraints to the effect that root edges coincide with PrWd edges. It is another variation on the Generalized Alignment schema, with GramCat taking the value Root (rather than Stem, as in Diyari):

(30) ALIGN-RT: Align (Root, Left/Right, PrWd, Left/Right).

The grammar of Dyirbal thus ranks ALIGN-RT higher than PARSE-SYLL and ALL-FT-L. ALIGN-ST is demoted to a ranking below ALL-FT-L, and I have not indicated it in (31):

(31)	a.	FT-BIN:	Feet are disyllabic trochees.
	b.	ALIGN-RT:	Align (Root, Left/Right, PrWd, Left/Right).
	c.	PARSE-SYLL:	Every syllable belongs to a foot.
	d.	ALL-FT-L:	Align (Foot, Left, PrWd, Left)

Tableaux are given in (32):

(32a) / {burgurrum}-bu/	ALIGN-RT	PARSE-SYLL	ALL-FT-L
i. ☞ [[(búr.gu).rrum]-bu]		**	
ii. [(búr.gu).(rrùm-bu)]	* !		bur.gu

(32b) / {waynydyi}-ngu-gu /	ALIGN-RT	PARSE-SYLL	ALL-FT-L
i. ☞ [[(wáynydyi)]-(ngù-gu)]			way.nydyi
ii. [[[(wáynydyi)]-ngu]-gu]		* ! *	

(32c) / {banagay}-mba-ri-nyu /	ALIGN-RT	PARSE-SYLL	ALL-FT-L
i. ☞ [[(bá.na).gay]-(mbà-ri)-nyu]		**	ba.na.gay
ii. [[(bá.na).gay]-mba-(rì-nyu)]		**	ba.na.gay.mba !
iii. [[[[(bá.na).gay]-mba]-ri]-nyu]		**	
iv. [(bá.na).(gày-mba)-(rì-nyu)]	* !		ba.na, ba.na.gay.mba

(32d) /{banagay}-na-mbila /	ALIGN-RT	PARSE-SYLL	ALL-FT-L
i. ☞ [[(bà.na).gay]-(nà-mbi).la]		**	ba.na.gay
ii. [[(bà.na).gay]-na-(mbì.la)]		**	ba.na.gay.na !
iii. [[[(bà.na).gay]-na]-(mbì.la)]		**	ba.na.gay.na !
iv. [(bà.na).(gày-na)-(mbì.la)]	* !		ba.na, ba.na.gay.na

PrWd structures are independently motivated by phonotactic constraints of the language. Dyirbal syllables have obligatory onsets. The PrWd boundary after the root predicts the absence of (re)syllabification of a root-final consonant with a following suffixal vowel. This is confirmed by three phonotactic rules of Dyirbal (Dixon 1972: 272-274). First, all affixes begin with a single consonant, just as roots. That is, affixes cannot take the root-final consonant as their onset. Second, root-final consonants are limited to the set {m, n, n^y, l, r, rr, y} excluding obstruents and /ŋ/, i.e. essentially the set of possible coda's. That is, by the following PrWd boundary, the root-final consonant must be syllabified as a coda. Third, at a root-affix boundary, certain consonant clusters (e.g. /n^yŋ/) which are ruled out in morpheme-internal contexts are allowed. The wider range of clusters follows directly from the PrWd boundary after the root.

5. Warlpiri

Warlpiri is a Pama-Nyungan language spoken in the Northern Territory, Australia (Nash 1986). Its stress pattern is partly identical to that of Diyari and Dyirbal, as witnessed by the words of (33). Secondary stresses fall on (i) the initial syllable of polysyllabic morphemes, and (ii) on the third syllable of four syllable morphemes.

(33)	a.	2	wáti	'man'
	b.	3	wátiya	'tree'
	c.	4	mánangkàrra	'spinifex plain'
	d.	2+1	wáti-ngka	'man-LOC'
	e.	2+2	ngáti-nyànu	'mother-POSS'
	f.	2+3	yárla-kàrlangu	'yam species-digger'
	g.	3+2	yáparla-ngùrlu	'FaMo-ELAT'
	h.	2+2+1	yápa-rlàngu-rlu	'person-e.g.-ERG'
	i.	4+1	mánangkàrra-rla	'spinifex-LOC'

	j.	4+4	ngátinyànu-ngàtinyànu	'mother-POSS-PL'

Observe the minimal stress pair (attributed by Nash to K. Hale) formed by the segmentally identical examples in (33g, h). This pair shows that the morphological interpretation of words may crucially depend on prosodic information. It provides an ideal example of how demarcative stress can actually have a distinctive function as well, even in a so-called *fixed* stress language, where stress is entirely predictable.

Warlpiri differs from Diyari and Dyirbal in the words of (34). Secondary stress falls on the third syllable of a trisyllabic root followed by a single monosyllabic suffix (cf. 34a), and on the first syllable in a sequence of monosyllabic suffixes (cf. 34b-h).

(34)	a.	3+1	wátiyà-rla	'tree-LOC'
	b.	2+1+1	yíri-mà-ni	'sharp-CAUS-NPast'
	c.	3+1+1	wátiya-rlà-rlu	'tree-LOC-ERG'
	d.	4+1+1	mánangkàrra-rlà-rlu	'spinifex-LOC-ERG'
	e.	2+1+1+2	páka-rnì-nja-kùrra	'hit-NPast-INF-OBJCOMP'
	f.	2+2+1+1	párnka-pàrnka-mì-rra	'run-run-NPast-forth'
	g.	3+1+1+2	wírnpirli-jà-lpa-jàna	'whistle-PAST-AUX-them'
	h.	4+1+1+2	wálapàrri-rnì-nja-kùrra	'test-NPast-INF-OBJCOMP'

In contrast to Diyari, Warlpiri has alternating stress in series of monosyllabic affixes. As in Dyirbal, alternating stress starts on the first post-root syllable, except in (34a), where a final syllable of a trisyllabic root has secondary stress before a single monosyllabic affix. Warlpiri is similar to Diyari, but not to Dyirbal, in having consistent initial stress in polysyllabic affixes. Recall that Dyirbal has an option of leaving the first syllable of a disyllabic suffix unstressed.

Let us now consider how Warlpiri differs from Diyari and Dyirbal. First, some constraint is required to the effect that poly-syllabic affixes are stressed on their initial syllables. That is, all left edges of poly-syllabic morphemes are PrWd boundaries, to be respected by the foot parse. In (35), I use curly brackets to indicate left edges of polysyllabic morphemes:

(35)		*Morphological structure*	*PrWd structure*
	a.	{watiya-rla	[watiya-rla]
	b.	{yíri-mà-ni	[yíri-mà-ni]
	c.	{paka-rni-nja-{kurra	[paka-rni-nja]-[kurra]
	d.	{wirnpirli-ja-lpa-{jana	[wirnpirli-ja-lpa]-[jana]

This can be achieved by the following constraint:

(36) ALIGN-MO-L: Align (Morpheme, Left, PrWd, Left)

Notice that ALIGN-MO-L does not refer to 'poly-syllabic morpheme'. If undominated, it would result in left PrWd brackets at the left edge of every affix, producing the incorrect structures of (37ab) rather than the correct structures of (37cd).

(37) a. [(wáti)ya]-[rla] b. [(yíri)]-[ma]-[ni]
c. [(wàti)(yà-rla)] d. [(yíri)]-[(mà-ni)]

However the structures (37ab) are ruled out by the stronger requirement that each Prosodic Word is minimally a (binary) foot. This is achieved by an undominated constraint ALIGN-WD-L:

(38) ALIGN-WD-L: Align (PrWd, Left, Foot, Left)

In (37c-d), ALIGN-MO-L is minimally violated to satisfy a higher ranking constraint, ALIGN-WD-L. The grammar of Warlpiri stress is stated in (39):

(39) a. FT-BIN: Feet are disyllabic trochees.
b. ALIGN-WD-L: Align (PrWd, Left, Foot, Left)
c. ALIGN-MO-L: Align (Morpheme, Left, PrWd, Left).
d. PARSE-SYLL: Every syllable belongs to a foot.
e. ALL-FT-L: Align (Foot, Left, PrWd, Left)

Let us now consider some crucial tableaux. In the outputs I have indicated the PrWd with square brackets. From (40b) on, I do not consider outputs which violate FT-BIN:

(40a) / watiya-rla /	FT-BIN	ALIGN-WD-L	ALIGN-MO-L	PARSE-SYLL	ALL-FT-L
i. ☞ [(wá.ti).(yà-rla)]			*		wa.ti
ii. [[(wá.ti).ya]-rla]			*	* ! *	
iii. [(wá.ti).ya]-[rla]		* !		**	

(40b) / watiya-rla-rlu /	FT-BIN	ALIGN-WD-L	ALIGN-MO-L	PARSE-SYLL	ALL-FT-L
i. ☞ [(wá.ti).ya]-[(rlà-rlu)]			*	*	wa.ti.ya
ii. [(wá.ti).(yà-rla)-rlu]			** !	*	wa.ti
iii. [[[(wá.ti).ya]-rla]-rlu]			** !	***	
iv. [(wá.ti).ya]-[rla]-[rlu]		* ! *		*	

(40c) / yaparla-ngurlu /	FT-BIN	ALIGN-WD-L	ALIGN-MO-L	PARSE-SYLL	ALL-FT-L
i. ☞[(yá.pa).rla]-[(ngù.rlu)]				*	ya.pa.rla
ii. [(yá.pa).(rlà-ngu).rlu]			* !	*	ya.pa

(40d) / yapa-rlangu-rlu /	FT-BIN	ALIGN-WD-L	ALIGN-MO-L	PARSE-SYLL	ALL-FT-L
i. ☞ [(yá.pa)]-[(rlà.ngu)-rlu]			*	*	ya.pa
ii. [(yá.pa)]-[rla.(ngù-rlu)]			*	*	ya.pa.rla!

(40e) / manangkarra-rla /	FT-BIN	ALIGN-WD-L	ALIGN-MO-L	PARSE-SYLL	ALL-FT-L
i. ☞ [(má.nang).(kà.rra)-rla]			*	*	ma.nang
ii. [(má.nang).ka.(rrà-rla)]			*	*	ma.nang.ka!
iii. [(má.nang).ka.rra-rla]			*	** ! *	
iv. [(má.nang).(kà.rra)]-[rla]		* !		*	ma.nang

A further alignment constraint is relevant in a set of data which I have not introduced. Verbs consist of a verb stem plus an Auxiliary word, which contains aspectual and pronominal suffixes. Secondary stresses within the Auxiliary word alternate rightward on monosyllabic suffixes, the final of which is unstressed. I indicate the right edge of the verb stem by "#":

(41) a. wángka-mi # ka
'to speak-NPast-PRES'
b. wángka-mi # kà-rna
'to speak-NPast-PRES-I'
c. wángka-mi # kà-rna-ngku
'to speak-NPast-PRES-I-You'
d. wángka-mi # kà-rna-ngkù-lu
'to speak-NPast-PRES-I-You-PL'
e. wángka-mi # kà-rna-ngkù-lu-rla
'to speak-NPast-PRES-I-You-PL-DAT'

The Auxiliary word behaves as an independent domain for stress. This result can be achieved by the following undominated constraint:

(42) ALIGN-V-R: Align (Verb Stem, R, PrWd, R)

The analysis is illustrated by the following tableaux, where I omit FT-BIN. To save space, I have indicated violations of ALL-FT-L by numbers, rather than by full syllables:

(43a) /wangka-mi # ka/	AL-V-R	AL-WD-L	AL-MO-L	PARSE-SYLL	ALL-FT-L
i. ☞ [[(wángka)-mi]-ka]			**	**	
ii. [[(wángka)]-mi]-[ka]		* !	*	**	
iii. [[(wángka)]-[(mì-ka)]	* !		*		2

(43b) /wangka-mi # ka-rna/	Al-V-R	Al-Wd-L	Al-Mo-L	Parse-Syll	All-Ft-L
i. ☞ [(wángka)-mi]-[(kà-rna)]			**	*	3
ii. [(wángka)-mi]-[ka-rna]		* !	**	***	
iii. [(wángka)]-[(mì-ka)-rna]	* !		**	*	2

(43c) /wangka-mi # ka-rna-ngku/	Al-V-R	Al-Wd-L	Al-Mo-L	Parse-Syll	All-Ft-L
i. ☞ [(wángka)-mi]-[(kà-rna)-ngku]			***	**	3
ii. [[(wángka)-mi]-ka]-[(rnà-ngku)]			***	**	4 !
iii. [(wángka)-mi]-[ka-(rnà-ngku)]		* !	***	**	4
iv. [(wángka)]-[(mì-ka)]-[(rnà-ngku)]	* !		***		2, 4

(43d) /wangka-mi # ka-rna-ngku-lu/	Al-V-R	Al-Wd-L	Al-Mo-L	Parse-Syll	All-Ft-L
i. ☞ [(wángka)-mi]-[(kà-rna)]-[(ngkù-lu)]			***	*	3, 5
ii. [[(wángka)-mi]-ka]-[(rnà-ngku)-lu]			**** !	***	4
iii. [(wángka)-mi]-[ka-(rnà-ngku)-lu]		* !	****	***	4
iv. [(wángka)-[(mì-ka)]-[(rnà-ngku)-lu]	* !		***	*	2, 4

(43e) /wangka-mi # ka-rna-ngku-lu-rla/	Al-V-R	Al-Wd-L	Al-Mo-L	Parse-Syll	All-Ft-L
i. ☞ [[[(wángka)]-mi]-(kà-rna)-(ngkù-lu)-rla]				**	3, 5
ii. [[[(wángka)]-mi]-(kà-rna)-ngku-(lù-rla)]				**	3, 6 !
iii. [[[(wángka)]-mi]-ka-(rnà-ngku)-(lù-rla)]				**	4 !, 6
iv. [[(wángka)]-(mì-ka)-(rnà-ngku)-(lù-rla)]	* !				2, 4, 6

Let us now consider a rule-based metrical account of Warlpiri stress. On the one hand, it is clear that setting up each morpheme as an independent stress domain (the Halle & Vergnaud analysis of Diyari) does not work for Warlpiri, as foot construction may cross morpheme edges, in contrast to the situation in Diyari. On the other hand, a cyclic analysis based on monosyllabic feet and monosyllabic foot destressing also fails. Poser (1989:142) proposes a post-cyclic *Merger* rule for Warlpiri which restructures two monosyllabic feet into a single disyllabic foot. See (44):

```
(44)     (*      )         (*            )        (*          )
         (*  .)(*)  Foot   (*  .)(*)   (*)  Merger (*  .)(*   .)
        [wáti yà] =>     [wáti yà -rlà] =>     [wátiyàrla]
```

Merger misses the generalization of foot binarity. A further complication resides in the fact that *Merger* must apply directionally from right to left, as demonstrated by (45):

```
(45)     (*                   )          (*              )
         (*  .)(*)   (*)  (*)   Merger  (*  .)(*)(*   .)
        [wáti yà -rlà-rlù]   =>     [wáti yàrlàrlu]

              (*            )
              (*  .). (*   .)
        =>    [wátiyarlàrlu]
```

It is unclear why *Merger* applies leftward, while foot construction is rightward. Observe that *Merger* must be followed by *Monosyllabic Destressing* to eliminate the monosyllabic foot on the third syllable of (45). Monosyllabic destressing constitutes a further indication of the missed generalization of foot binarity. Finally, *Merger* runs into empirical problems with respect to the Auxiliary word pattern of (41). Leftward *Merger* predicts the incorrect patterns of (46):

(46) a. *wángka-mi # ka-rnà-ngku
'to speak-NPast-PRES-I-You'
b. *wángka-mi # ka-rnà-ngku-lù-rla
'to speak-NPast-PRES-I-You-PL-DAT'

To repair this defect, it must be stipulated that *Merging* applies rightward, rather than leftward, in Auxiliary words. This stipulation is completely ad hoc.

To wind up the discussion of Warlpiri, an OT analysis has clear advantages. First, it directly expresses foot binarity. Secondly, since it does not rely on directional foot construction, it does not produce conflicting directionalities of foot construction versus foot restructuring (Poser's *Merging*) on the one hand, or of foot restructuring in Auxiliary words versus foot restructuring in all other cases on the other hand.

Comparing Diyari, Dyirbal and Warlpiri, we find differences in the constraints aligning morphological domains and PrWds. Diyari aligns *right stem* edges with PrWd edges. Dyirbal instead aligns *right root* edges with PrWd edges. Warlpiri aligns *right verb stem* edges with PrWd edges, as well as *left morpheme* edges with PrWd edges.

6. Conclusions

In this paper I hope to have shown that the functional view of the demarcative property of word stress is by no means incorrect. It only suffers from a lack of formalization. I have proposed that this morpheme-edge-marking function of stress can be formalized as a special case of Generalized Alignment, a notion from McCarthy and Prince (1993). This representational approach of the prosody-morphology interface contrasts sharply with standard rule-based derivational theory, which reduces morpheme-edge marking to a rule-conspiracy. The vagueness in the notion of 'morpheme-edge-marking function' was further reduced by explicitness about the interaction between alignment principles and other grammatical principles, such as foot well-formedness. This interaction can be adequately viewed as constraint interaction in the sense of Prince and Smolensky (1993). In this sense, this paper also contributes to the quickly expanding body of literature on the rôle of constraints in linguistic theory. Finally, if Generalized Alignment of prosodic and morphological edges forms linguistic knowlegde, it is only natural that speakers use it actively in morphological parsing. Prosody-morphology alignment can then be seen as a contribution to the robustness of morphological parsing.

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