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Headed spans and autosegmental spreading

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1. Introduction

Assimilation as feature spreading is a central insight of autosegmental phonology (Goldsmith 1976a, 1976b). The idea is that assimilation increases the temporal span of a tone or distinctive feature to encompass more than a single segment. In autosegmental phonology, which coordinates features and segments via association lines, spreading is insertion of these lines.

For example, in Johore Malay (Onn 1976), nasality spreads rightward, affecting vowels and glides: /pəŋawasan/ → *pəŋãw̃ãsan* 'supervision'. In most implementations of autosegmental phonology, this sort of spreading is produced by iterative association rules like (1).[1]

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[1]In the earliest literature on autosegmental phonology such as Goldsmith (1976a, 1976b) or Clements and Ford (1979), spreading was effected by constraints rather than rules. In place of iteration, which makes sense for rules but not constraints, Clements and Ford recruit the Q variable of Halle (1975). This approach abstractly resembles the SPREAD constraints, which are discussed in section 3.3.9.

(1) Iterative spreading rule

[+nas]

[+seg] [–cons]   Direction: Left-to-right

Iterative rules apply to their own output, proceeding directionally until no further changes can be made (Anderson 1980, Howard 1972, Johnson 1972, Kenstowicz and Kisseberth 1977, and others). Spreading therefore continues until it runs out of segments or is blocked by a segment with an incompatible feature specification (e.g., true consonants in Johore Malay).

When Optimality Theory (Prince and Smolensky 1993) is applied to autosegmental phonology, the obvious assumption is that candidates can differ in the extent of feature spreading. Among the candidates in Johore Malay, then, are the winner *pəŋãw̃ãsan* and losers where spreading has gone too far (**pəŋãw̃ãs̃ãn*) or not far enough (**pəŋãwasan*, **pəŋawasan*). A markedness constraint against *s̃* stops nasality from spreading too far. A 'pro-spreading' markedness constraint, ranked below **s̃*, favors *pəŋãw̃ãsan* over the alternatives **pəŋãwasan* and **pəŋawasan*.

The goal of this article is to answer the following question: what is this pro-spreading markedness constraint? In response, I propose a theory of *spans*. The segments of a word are exhaustively parsed into constituents called spans that approximate the associations borne by autosegmental features. Unlike autosegmental representations, however, spans each have a head segment, which determines the pronunciation of the other segments in the span. The effect of spreading is obtained from exhaustive parsing and from a constraint that prohibits adjacent spans; this constraint is opposed by faithfulness and markedness constraints that require certain segments to be the heads of spans. I will be using nasal harmony to illustrate Span Theory, but it should be understood that this theory is offered as a general approach to all spreading processes, featural and tonal.

The OT literature contains many other ideas about the constraint that favors maximal spreading. I will show (section 3) that Span Theory solves various problems with these other proposals. Section 4 summarizes the results and discusses some further issues.

2. Span Theory

2.1 Overview

In Span Theory, the segments of a word are exhaustively parsed into spans for each distinctive feature. Each span of the feature [F] has a head segment, and it is the head segment's value for [F] that determines the pronunciation of the other segments in the span. In additition to these representational assumptions, four constraint-types are posited:

(i) A markedness constraint that is violated by adjacent [F]-spans. This constraint replaces the ALIGN or AGREE constraints of other theories of spreading (see section 3).

(ii) Faithfulness constraints requiring input [αF] segments to head [αF] spans in the output. They are Span Theory's alternative to IDENT.

(iii) Markedness constraints requiring certain segment types to head spans with a particular [F]-value. These constraints are essentially feature cooccurrence restrictions.

For formalization of autosegmental phonology, see Kornai (1994) and Pierrehumbert and Beckman (1988).

(iv) Markedness constraints requiring the head segment to lie at a particular edge of a span. These constraints produce directionality effects similar to ALIGN, but without ALIGN's problems (see section 3.3).

We will now look at these assumptions in greater detail.

2.2 Properties of spans

I will begin with the representational assumptions — that is, the assumptions about GEN. A featural *span* is defined as a constituent whose terminal nodes are segments in a contiguous string. There are different spans for each distinctive feature, analogous to the tiers of autosegmental phonology. The partitioning of segments into spans is exhaustive and nonoverlapping: every segment belongs to exactly one span for each distinctive feature. These assumptions closely resemble the association conventions of early autosegmental phonology (Clements and Ford 1979, Goldsmith 1976a, 1976b): 'every tone bearing unit is associated with some tone' ≈ exhaustive parsing into spans *and* 'association lines do not cross' ≈ spans are nonoverlapping.[2]

Exactly one segment of every span is designated as the span's *head.* All of the segments in a span of the feature [F] are pronounced with the head segment's value for [F]. Of course, a segment may head a span for some features but not others. A span can consist of just a single segment, which is necessarily the head, up to all of the segments in a word, of which just one is the head. In OT, the idea of designating heads in autosegmental representations has been developed and studied by Smolensky (1995, 1997, 2005) and in Optimal Domains Theory (Cassimjee and Kisseberth 1989, 1997, 1998, Cole and Kisseberth 1995a, 1995b, 1995c). Pre-OT, metrical theories of harmony involved similar notions (Halle and Vergnaud 1978, Leben 1982, Zubizarreta 1979), which are a natural extension of a concept that is pervasive throughout grammar (as has been recognized since Harris 1946).

The requirement that spans consist of contiguous segmental strings, combined with the assumption that all segments in a span are pronounced with the head's feature value, are more or less equivalent to the proposal that spreading is always strictly local, with no skipping allowed (Gafos 1999, Ní Chiosáin and Padgett 2001, Walker 1998b and others). In the end, however, it may prove necessary and even desirable to retreat from the assumption that all segments in a span are pronounced with the head's feature or tone value. One possibility is that a segment may be physically unable to express the head's feature. This is essentially the analysis that Walker (1998b: 49-50) and Walker and Pullum (1999) supply for the apparent skipping of laryngeals in nasal harmony (e.g., Sundanese *mĩʔãsih* 'to love'). Another possibility is that the pronunciation is determined by violable constraints, as in Optimal Domains Theory. Perhaps the most interesting point, however, is that Span Theory is highly congenial to a target-and-interpolation model of phonetic interpretation (e.g., Choi 1992, Cohn 1990, Huffman 1990, Keating 1990, Janet Pierrehumbert 1980, Janet Pierrehumbert and Beckman 1988). The 'targets' are just the heads of spans. The phonetic interpretation of a headed span need not involve steady-state reproduction of the head's feature value throughout the span. The phonetic interpretation could just as well involve a gradual approach to and/or decline from the span head's target value.

[2] Autosegmental phonology allows minimal overlap to accommodate segmental and tonal contours (Anderson 1976, Goldsmith 1976a), as do ambisyllabicity (Kahn 1976), or metrical foot 'intersections' (Hyde 2002). It would not be difficult to modify Span Theory to allow similar overlap (though see Duanmu 1990 on the question of whether tonal contours exist).

Autosegmental notation, augmented with some indication of headship, could be used to represent spans. But because autosegmental notation is cumbersome, particularly in tableaux, I will opt for a bracketing approach. A form like *mã w̃ã sa* will be represented as *($\underline{m}$awa)($\underline{s}$a)*, with two [nasal] spans delimited by parentheses and the head segments of each underlined. The head feature [nasal] will not be indicated explicitly, since we are usually talking about one harmonizing feature at a time, though when necessary the span's head feature value can be marked on the head segment: $(\underline{m}_{[+nas]}awa)(\underline{s}_{[-nas]}a)$ or $(\underline{m}_{N}awa)(\underline{s}_{O}a)$.

Under these assumptions about GEN, the segmental string *mawasa* can be parsed into [nasal] spans in any of the ways in (2), as well as others.

(2) Some candidates from /mawasa/ and their prounounciations

($\underline{m}$awa)($\underline{s}$a)	[mãw̃ãsa]
($\underline{m}$a)($\underline{w}$asa)	[mãwasa]
($\underline{m}$a)($\underline{w}$a)($\underline{s}$a)	"
($\underline{m}$)(awa$\underline{s}$a)	[mawasa]
($\underline{m}$)(awas$\underline{a}$)	"
($\underline{m}$)($\underline{a}$)($\underline{w}$)($\underline{a}$)($\underline{s}$)($\underline{a}$)	"
($\underline{m}$)($\underline{a}$wasa)	"
etc.	

It's obvious that many pronunciations are structurally ambiguous.[3] As we will see, the constraint set is sufficiently rich that there is usually no such ambiguity in the output of EVAL, however.

These assumptions about GEN also mean that many imaginable representations are not permitted and so they will never compete with the forms in (2). A few of them are listed in (3), together with comments about why they are impossible.

(3) Some span parses not allowed by GEN

($\underline{m}$awa)sa	Non-exhaustive parsing into [nasal] spans.
($\underline{m}$a)wa($\underline{s}$a)	Same.
($\underline{m}$a)($\underline{w}$a$\underline{s}$a)	Two-headed span.
($\underline{m}$awa)(sa)	Headless span.

2.3 Principal constraints on spans

Span Theory also requires some emendations of CON to reflect its novel representational assumptions, particularly headedness. One class of constraints, which regulate span head location, will be discussed in section 2.6; meanwhile, we'll confine our attention to left-headed spans. The other classes of constraints deal with span adjacency, faithfulness, and feature cooccurrence.

A family of markedness constraints, one for each distinctive feature or tone, prohibits adjacent spans. See (4) for a definition.[4]

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[3]Similar structural ambiguities are found in classic autosegmental phonology as well. For instance, *mã* can be represented with one doubly-linked [+nasal] or two singly-linked features. The OCP is typically called on to resolve this structural ambiguity, and *A-SPAN in (4) has similar effects in Span Theory.

[4]I am very grateful to Maria Gouskova for suggesting this formulation of the anti-span constraint. My previous version, *SPAN, suffered from the liabilities of economy constraints that are identified in Gouskova (2003).

(4) *A-SPAN(F)

Assign one violation mark for every pair of adjacent spans of the feature [F].

Because parsing into spans is exhaustive and non-overlapping, any form with more than one [F] span must violate *A-SPAN(F) at least once. In general, the number of violation-marks that *A-SPAN(F) assigns to a candidate is equal to one less than the number of F spans in that candidate. Note that *A-SPAN(F) is violated even if the adjacent spans have heads with the same value for [F]. For example, *(m̲a)(w̲a)(s̲a)* incurs two marks from *A-SPAN(nasal), despite the fact that the spans *(w̲a)* and *(s̲a)* are both oral.

Though nothing quite like *A-SPAN can be found in earlier work, there are some precedents. AGREE (see section 3.1) requires adjacent segments or syllables to have the same feature or tone value; *A-SPAN also refers to adjacent elements, but it refers to spans and not segments and it is violated even if the adjoining spans have the same feature value as head. The feature-driven markedness theory of harmony (see section 3.2) is perhaps a closer match, but it lacks Span Theory's notion of headship.

Two kinds of constraints favor parsing segments as the heads of spans. On the faithfulness side, IDENT and MAX-feature constraints are replaced by FTHHDSP, defined as in (5).[5,6]

(5) FTHHDSP(αF)

If an input segment ς_I is [αF] and it has an output correspondent ς_O, then ς_O is the head of an [αF] span.

For example, FTHHDSP(+nasal) is violated under either of the following conditions: an input [+nasal] segment has an output correspondent that is the head of an oral span; or an input [+nasal] segment has an output correspondent that is not the head of any span of the feature [nasal]. Therefore an input [+nasal] segment can have an output correspondent that is pronounced as nasal yet still violate FTHHDSP(+nasal): the /w̃/ in /maw̃a/ → *(m̲awa)* is an example. This may seem surprising, but it's actually entirely consistent with standard autosegmental theory. Formally, there is a difference between a representation with two [+nasal] features, one linked to [m] and one to [w̃], and a representation with a single [+nasal] feature [m] and [w̃] they share. FTHHDSP(+nasal) says, in effect, that this difference is enough to constitute a breach of faithfulness. In short, the FTHHDSP constraints are the result of taking autosegmental representations seriously. (See 3.3.8 for justification of this definition of FTHHDSP.)

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[5]Lee Bickmore raises the question of how to represent floating tones or other features in the input and output. FthHdSp as defined in (5) is segment-based, so it does not enforce faithfulness to input elements that are not attached to segments. But there are well-established proposals for enlarging the theory of faithfulness to include input floating elements (e.g., Lombardi 1998, Zoll 1996), and these proposals can be adapted to Span Theory.

The case of output floating elements is different. To my knowledge, the only floating output elements that actually affect phonetic interpretation are the floating low tones invoked in some theories of downstep (Clements and Ford 1979). There is no natural analogue to this approach in Span Theory. On the other hand, Span Theory is fully compatible with a theory of downstep in which the second of two adjacent high-tone spans is downstepped relative to the first (e.g., Clark 1990, Odden 1982).

[6]I take no position on whether span structure is present in inputs as well as outputs, though the null hypothesis (dubbed 'homogeneity' by Moreton (2003)) is that inputs and outputs are made out of exactly the same stuff. One possibility, at least for non-tonal features, is that input spans are always monosegmental, so every input segment is the head of a span of every feature. Then FTHHDSP is more obviously a faithfulness constraint in the sense of requiring identity between input and output.

On the markedness side, span headship is also demanded by certain feature cooccurrence restrictions. A general schema for such constraints is given in (6).

(6) HEAD([βG, γH, ...], [αF])
Every [βG, γH, ...] segment heads a [αF] span.

The exact details of the Head constraints will depend on substantive properties of the features or tones involved. A set of HEAD constraints for [–nasal] spans is given in (8).

The overall picture that emerges from these assumptions about GEN and CON is one in which the difference between harmony and non-harmony depends on the ranking of *A-SPAN(F) relative to FTHHDSP(αF) and HEAD(X, [αF]). The FTHHDSP and HEAD constraints require relatively more [F]-spans, perhaps as many as one [F]-span for every segment. *A-SPAN(F), on the other hand, is violated by any candidate that contains more than one [F]-span, adding one violation for each additional span. Details aside, harmony is expected when *A-SPAN is ranked higher, whereas disharmony is permitted when either or both of FTHHDSP and HEAD takes priority.

2.4 Application to nasal harmony

To illustrate these concepts, I will use the well-studied phenomenon of nasal harmony. First some background.[7] Walker, drawing on her own research and earlier work (see Walker 1998b: 33 and references cited there), proposes that the blockers of nasal harmony follow a hierarchy that approximates the sonority scale (except for the nasal stops themselves). In Sundanese, glides and all less sonorant segments are blockers: *mãwur* ‘to spread’. In Johore Malay, glides are undergoers of harmony, but liquids and all less sonorant segments are blockers: *pəŋãw̃ãsan*, *mə̃ratappi* ‘to cause to cry’. In Kolokuma Ijo, liquids and glides can nasalize, but less sonorous segments cannot: *ɟ̃ãɾ̃ĩ* ‘shake’, *izõŋgo* ‘jug’. And in Applecross Gaelic, even fricatives nasalize, though obstruent stops never do: *s̃ŋ̃ã ɾ̃ʲdʲan* ‘thread’.

To account for these observations, Walker proposes the fixed hierarchy of nasal incompatibility constraints in (7).

(7) Nasal incompatibility (after Walker 1998b: 36)

*NASOBSTSTOP	≡ *[+nas, –cont, –son]
>>	
*NASFRICATIVE	≡ *[+nas, +cont, –son]
>>	
*NASLIQUID	≡ *[+nas, +approx, +cons]
>>	
*NASGLIDE	≡ *[+nas, +approx, –cons, –syll]
>>	
*NASVOWEL	≡ *[+nas, +approx, –cons, +syll]

Since the rankings among these constraints are fixed, if no other relevant constraints are in CON, a language can permit nasalized liquids only if it also permits nasalized glides, but not vice-versa. In

[7]For a dependency approach to nasal harmony and related phenomena, see Botma (2004)

Walker's factorial typology, the disposition of faithfulness and a pro-spreading markedness constraint (for her, a version of SPREAD) within this hierarchy is what determines the blocking segments and the nasality contrasts in a language.

Span Theory expresses the same basic insight, but the execution is somewhat different. Instead of the constraints in (7) that forbid certain segments from linking to [+nasal], there are the constraints in (8) that require those segments to head oral spans (see (6) on HEAD constraints).

(8) Required oral headedness (replaces (7))

HEAD([–cont, –son], [–nas]) ‘Every obstruent stop heads an oral span.’ (= OBSTHDOR)
>>
HEAD([+cont, –son], [–nas]) ‘Every fricative heads an oral span.’ (= FRICHDOR)
>>
HEAD([+app, +cons], [–nas]) ‘Every liquid heads an oral span.’ (= LIQHDOR)
>>
HEAD([+app, –cons, –syll], [–nas]) ‘Every glide heads an oral span.’ (= GLIHDOR)
>>
HEAD([+app, –cons, +syll], [–nas]) ‘Every vowel heads an oral span.’ (= VOWHDOR)

Throughout, I will use the more memorable names at the right when I refer to these constraints.

If a segment is required to be the head of a [–nasal] span, then it obviously interrupts any nearby nasal span — it ‘blocks spreading’, to use terminology that is familiar though not precisely accurate in the current context. The difference between *(ma)(wa)(sa)* (pronounced [mãwasa]) and *(mawa)(sa)* (pronounced [mãw̃ãsa]) is that *(ma)(wa)(sa)* satisfies GLIHDOR but *(mawa)(sa)* doesn't. Both of these candidates satisfy FRICHDOR, and both incur three marks from VOWHDOR.

Formally, blocking effects in nasal harmony are a result of ranking *A-SPAN(nasal) below one of the constraints in (8). In Johore Malay, it will be recalled, glides undergo nasal harmony but less sonorous segments block it. Therefore, *A-SPAN(nasal) is ranked below LIQHDOR and above GLIHDOR, as shown in (9). (For now, I do not consider candidates containing spans with noninitial heads. See the discussion of directionality in section 2.6.)

(9) Johore Malay-type system (vowels and glides as undergoers)

/mawasa/	OBSTHDOR	FRICHDOR	LIQHDOR	*A-SPAN(nasal)	GLIHDOR	VOWHDOR
a. ☞ (mawa)(sa)				*	*	***
b. (mawasa)		*!			*	***
c. (ma)(wa)(sa)				**!		***
d. (m)(a)(w)(a)(s)(a)				*****!		

The candidate with just a single span, (9b), is ruled out by high-ranking FRICHDOR, since its *s* is not the head of an oral span. All other candidates satisfy FRICHDOR and the other high-ranking headedness constraints (the latter are vacuously satisfied), leaving the decision up to *A-SPAN. It favors fewer spans, and so (9a) is the winner: it has just one pair of adjacent spans, while (9c) and (9d) have more.

By interpolating *A-SPAN(nasal) at other spots in the fixed hierarchy (8), we obtain the typology of blockers described by Walker. In a language where VOWHDOR dominates *A-SPAN(nasal), even vowels are blockers, so there is no nasal harmony at all, as in (9d). In Sundanese, vowels harmonize, but glides are blockers, so *A-SPAN is ranked between GLIHDOR and VOWHDOR. This favors *(ma)(wa)(sa)* (9c). In Kolokuma Ijo, *A-SPAN is ranked between FRICHDOR and LIQHDOR, so liquids and all more sonorous segments undergo harmony but fricatives block it. In Applecross Gaelic, *A-SPAN is ranked between OBSTHDOR and FRICHDOR, so even fricatives can nasalize, and candidates like (9b) win.

When Span Theory is applied to other features or tones, there will of course be other HEAD constraints, depending on the substantive properties of the segments involved. For example, spreading of [+ATR] is often blocked by low vowels (see Archangeli and Pulleyblank 1994a for extensive discussion), motivating a constraint HEAD([+low], [–ATR]). Similarly, voiced obstruents that block high-tone spreading (‘depressor consonants’) are affected by a constraint that requires voiced obstruents (or rather the syllables that contain them) to head low-tone spans.

2.5 The role of faithfulness

The schema for faithfulness constraints in Span Theory, FTHHDSP, was given in (5). FTHHDSP(αF) applies to input segments with the feature value [αF]. It says that their output correspondents, if any, must be parsed as the heads of [αF] spans. Heading a [–αF] span or failing to head any [F] span (even a [αF] span!) is a violation of this constraint.

For the example of nasal harmony, I am going to make an additional assumption that is not an essential element of Span Theory. With de Lacy (2002) and others (e.g., Gnanadesikan 1995/to appear, Howe and Pulleyblank to appear, Jun 1995, Kiparsky 1993), I assume that faithfulness constraints are more protective of marked feature values than unmarked ones. There are various ways of executing this basic idea; one is to say that FTHHDSP(+nasal) universally dominates FTHHDSP(–nasal).

In any language where underlying oral segments become nasalized through harmony, FTHHDSP(–nasal) must be ranked below *A-SPAN(nasal). In general, the FTHHDSP constraints encourage proliferation of spans, whereas *A-SPAN encourages economy of spans. Thus, the presence of harmony is an indication that FTHHDSP is dominated by *A-SPAN.

FTHHDSP(+nasal) also interacts with the oral headedness hierarchy (8). The constraints in (8) prefer orality, so they militate against preservation of nasal/oraldistinctions. For example, If FTHHDSP(+nasal) is ranked between GLIHDOR and VOWHDOR, as in (10), then vowels will contrast in nasality but glides will not.

(10) Effect of ⟦GLIHDOR >> FTHHDSP(+nasal) >> VOWHDOR⟧ on inventory

	GLIHDOR	FTHHDSP(+nasal)	VOWHDOR
/a/			
a. ☞ (a̲)			
b. (ã̲)			*!
/ã/			
c. ☞ (ã̲)			*
d. (a̲)		*!	
/w̃/			
e. ☞ (w̲)		*	
f. (w̲̃)	*!		

Under this ranking, an underlying nasalized vowel must head a [+nasal] span, despite VOWHDOR's demand that all vowels head [–nasal] spans. But the situation is just the opposite with glides: they head oral spans even at the cost of being unfaithful to the input.

By choosing different locations for FTHHDSP(+nasal) relative to the constraints in (8), a range of possible systems of nasal contrast can be obtained: contrast only in nasal stops; contrast in nasal stops and vowels; contrast in nasal stops, glides, and vowels; and so on. This consequence of ranking permutation matches the typological finding of Cohn (1993), Pulleyblank (1989), and Walker (1998b) that the implicational hierarchy for nasality in inventories approximates the implicational hierarchy for nasalizeability in harmony. Just as vowels are most easily nasalized in harmony, so too vowels will contrast in nasality more readily than glides. (There are some caveats — see below.)

Digression: The nasal stops occupy a special place in the system (see Walker 1998b: 85). In the *SPE* feature system (Chomsky and Halle 1968), all sonorant stops are necessarily [+nasal]. This means that HEAD([+son, –cont], [+nasal]) (or its equivalent, Walker's *NASOBSSTOP) is a universally inviolable constraint, a property of GEN rather than CON. As I just showed, languages without nasalized vowels (and glides, etc.) are languages where VOWHDOR dominates FTHHDSP(+nasal). But languages without any primary nasal consonants like *m* or *n*, of which there are a few (Hockett 1955: 119, Maddieson 1984: 62), are languages that simply prohibit sonorant stops: *[+son, –cont]. End of digression.

The picture becomes a bit more complicated when we look at the three-way interaction among the oral headedness constraints, FTHHDSP(+nasal), and *A-SPAN(nasal). For a language to have contrastive nasalization in vowels, it's not enough for it to have the ranking in (10), where FTHHDSP(+nasal) dominates VOWHDOR. FTHHDSP(+nasal) must also dominate *A-SPAN(nasal):

(11) ⟦FTHHDSP(+nasal) >> *A-SPAN(nasal)⟧ in language with vowel nasalization contrast

	FTHHDSP(+nasal)	*A-SPAN(nasal)
/ta/		
a. ☞ (t)(ã)		*
b. (ta)	*!	

We now have three ranking results ready to combine. From (9), we know that *A-SPAN(nasal) must dominate VOWHDOR in any language where nasality can spread to vowels. From (10) and (11), we know that FTHHDSP(+nasal) must dominate VOWHDOR and *A-SPAN(nasal) in any language with contrastively nasalized vowels. Therefore, if a language is to have contrastively nasalized vowels and nasal spreading onto vowels, it must have the ranking in (12).

(12) Ranking for vowel nasality contrast and nasal spreading onto vowels

/matã/	FTHHDSP(+nasal)	*A-SPAN(nasal)	VOWHDOR
a. ☞ (ma)(t)(ã)		**	**
b. (ma)(ta)	*!	*	**
c. (m)(a)(t)(ã)		***!	*

Walker (1998b: 67) cites Guahibo and Mixtec as examples of such a language.

This cannot be the whole story, however. Walker (1998b: 53-54, 63ff.) makes the point that the nasal incompatibility constraints in (7), which are the source of the oral headedness constraints in (8), cannot account for all observed restrictions on contrasting nasality. Although there is a reasonably good match between the implicational scale of nasal-harmony blockers and the implicational relations among nasalized segments in phonemic inventories, there are also some differences that Walker tentatively attributes to constraints on contrast (cf. Flemming 1995, Padgett 1997). An example of such a difference: according to Cohn (1993: 333), there are languages like Yakut and Koñagi that have contrastively nasalized continuant consonants but no nasalization contrast in vowels.

Further evidence for the insufficiency of the current system of constraints comes from languages like Warao.[8] In Warao, vowels contrast in nasality, whereas glides do not, but, as in Johore Malay, both vowels and glides become nasalized as a result of harmony. The ranking argument in (9) shows that vowels and glides can undergo harmony only if *A-SPAN(nasal) dominates GLIHDOR. The ranking argument in (12) shows that FTHHDSP(+nasal) dominates *A-SPAN(nasal) and VOWHDOR in any language with a vowel nasality contrast. By transitivity of domination, then, Warao has the ranking ⟦FTHHDSP(+nasal) >> GLIHDOR⟧, a ranking that wrongly predicts the existence of a nasality contrast in glides as well as vowels. Some further constraint, perhaps a constraint on contrast, is required to rule out distinctive nasality in glides. Since the same constraint

[8] My characterization of Warao as having distinctive nasality in vowels but not glides follows Osborn (1966: 112). Peng (2000) describes Warao differently, but he has subsequently (email, 1/25/2004) modified his position to agree with Osborn. See Walker (1998b: 67-79) for other languages of the Warao type.

is required to account for the inventories or Yakut or Koñagi, this does not seem like too much of a liability.

A full exploration of nasal harmony within Span Theory would of course need to confront these complications. But that is not the goal of this article. Rather, it's appropriate to conclude this section with some discussion of how FTHHDSP constraints might be involved in harmony of other features or of tones.

In general, spreading of the feature value [αF] requires the ranking ⟦FTHHDSP(αF) >> *A-SPAN(F) >> FTHHDSP(–αF)⟧. If, for example, high tones spread at the expense of low tones, then the operative ranking is ⟦FTHHDSP(H) >> *A-SPAN(T) >> FTHHDSP(L)⟧. This ranking is a necessary condition for high tone spread; other constraints may limit its effects. Among these other constraints are markedness constraints like HEAD, constraints on head location (section 2.6), positional faithfulness constraints (section 3.4.8), and perhaps a span binarity constraint to account for non-iterative spreading.[9] This list is not exhaustive — in fact, it seems likely that most if not all previously proposed constraints that limit spreading may have counterparts in Span Theory.

2.6 Directionality

In rule-based autosegmental phonology, spreading and other iterative processes have usually been regarded as directional: the targets of spreading must lie exclusively to the left or right of the trigger. Implementations of autosegmental phonology in OT are mostly similar, using inherently directional constraints like alignment to compel spreading (see section 3).

The need for freely stipulated directionality in harmony and other assimilation processes is by no means clear. Positional faithfulness, rather than directional spreading, is arguably responsible for many directional effects. Examples include root-controlled vowel harmony (McCarthy and Prince 1995) and vowel or nasal harmony controlled by the initial syllable or the stressed syllable (Beckman 1997, 1998, Padgett 1995b). Some directional effects in harmony might also be consequences of positional markedness (Steriade 1995, Zoll 1997, 1998), such as attraction of tones to the main-stressed or head syllable. Others may come from constraints on faithfulness to derived stems (Bakovic 2000).

Nasal harmony presents a fairly solid case where unbounded directional spreading cannot be explained with positional faithfulness or positional markedness, however. In Johore Malay, nasality spreads from left to right regardless of the target segments' position in the word or status as root or affix. Languages with unbounded right-to-left nasal harmony are decidedly less common (Walker 1998b: 69ff.), but they do exist. The case for unbounded bidirectional harmony is less clear from Walker's typological survey (in most of the bidirectional examples, nasality cannot be attributed to a specific underlying segment or the underlying [nasal] bearer has been deleted), but for the purposes of illustrating Span Theory I will disregard this caveat and attempt to derive a full typology with rightward, leftward, and bidirectional spreading.

In view of the general edge-tropism of constituent heads in metrical phonology and in syntax, it should come as no surprise that directionality of harmony is a consequence of constraints on the location of the head segment within its span. I postulate the four constraints in (13), which impose left or right headedness on oral and nasal spans.

[9] I am grateful to Lee Bickmore for raising the question about non-iterative spreading.

(13) Span head location

a.	SPHDL(+nasal)	≡ The head segment of a [+nasal] span is initial in that span. Assign one violation-mark for each non-conforming span.
b.	SPHDR(+nasal)	≡ The head segment of a [+nasal] span is final in that span. Assign one violation-mark for each non-conforming span.
c.	SPHDL(–nasal)	≡ The head segment of a [–nasal] span is initial in that span. Assign one violation-mark for each non-conforming span.
d.	SPHDR(–nasal)	≡ The head segment of a [–nasal] span is final in that span. Assign one violation-mark for each non-conforming span.

It should be noted that these constraints, though they mention edges, evaluate candidates categorically, not gradiently. This distinguishes them from ALIGN. The span's head is either at the designated edge or it isn't; distance from the edge is irrelevant (and never could be, if gradient constraints are banned from CON — see McCarthy (2003)).

To illustrate how these constraints control directionality, I will use a hypothetical example. Assume a language with the Johore Malay ranking in (9). Under this ranking, a segment-conserving parse of the input /asawamawasa/ cannot have fewer than three [nasal] spans because FRIHDOR dominates *A-SPAN(nasal), so the two *s*s are obligate heads, as is the *m*. The unranked tableau (14) evaluates the candidates with exactly three spans using the directionality constraints.

(14) Directionality possibilities

		SPHDL(+n)	SPHDR(+n)	SPHDL(–n)	SPHDR(–n)
a. Bidirectional	(as)(awamawa)(sa)	*	*	*	*
b. Right-to-left	(as)(awam)(awasa)	*		**	*
c. Left-to-right	(asawa)(mawa)(sa)		*	*	**
d. No harmony	(asawa)(m)(awasa)			**	**

The rankings that select these candidates are given in (15).

(15) Rankings controlling direction

a. Bidirectional harmony:	SPHDL(–nas) >> SPHDR(+nas)
	SPHDR(–nas) >> SPHDL(+nas)
b. Right-to-left harmony:	SPHDR(–nas) >> SPHDL(+nas)
	SPHDR(+nas) >> SPHDL(–nas)
c. Left-to-right harmony:	SPHDL(–nas) >> SPHDR(+nas)
	SPHDL(+nas) >> SPHDR(–nas)
d. No harmony:	SPHDL(+nas) >> SPHDR(–nas)
	SPHDR(+nas) >> SPHDL(–nas)

The directionality typology derives from the pairwise rankings of SPHDEdge(αnasal) with respect to SPHD¬Edge(–αnasal).

A fuller exploration of the directional typology appears in the appendix. It shows all of the logically possible span-parsings of /awamawa/. (To keep the size of the tableau reasonable, I have not considered candidates with the same span structure and different heads. The violation-marks are assigned under the assumption that *m* is the head of any span that contains it, *w* is the head of any span that contains it but not *m*, and *a* is the head of any span that contains it alone.) Besides the span head location constraints, the tableau includes *A-SPAN(nasal) and GLIHDOR, to show the effects of glides as blockers.

Using OTSoft (Hayes 1998), I have determined that 25 of these candidates can win under some ranking, but because of structural ambiguities, they represent only the 7 distinct pronunciations listed in (16).

(16) Pronunciations of possible winners in appendix

	Pronunciation	Examples of span structure
a.	awamawa	(a)(w)(a)(m)(a)(w)(a), (a)(w)(a)(m)(aw)(a), ...
b.	awamãwa	(a)(w)(a)(ma)(w)(a), (a)(wa)(ma)(wa), ...
c.	awamãw̃ã	(a)(wa)(mawa), (a)(w)(a)(mawa), ...
d.	awãmawa	(a)(w)(am)(a)(w)(a), (a)(w)(am)(a)(wa), ...
e.	awãmãwa	(a)(w)(ama)(w)(a), (a)(w)(ama)(wa), ...
f.	ãw̃ãmawa	(awam)(a)(w)(a), (awam)(a)(wa), ...
g.	ãw̃ãmãw̃ã	(awamawa), ...

All of these pronunciations seem like reasonable outcomes. In (16a) we have no nasal harmony at all, in (16b) we have rightward nasal harmony blocked by glides (and all other less sonorous segments), while (16c) is rightward harmony where glides are not blockers (though other, less sonorous segments might be). The forms in (16d–f) are just the mirror images of (16a–c), with leftward harmony rather than rightward. Finally, (16g) is bidirectional harmony with no blockers.

Although these refinements to Span Theory can derive a basic directional typology, they are crucially incomplete in at least one respect: they are unable to obtain 'process-specific' blocking effects (Davis 1995, McCarthy 1997, Prince 1997, Walker 1998b: 51-52).[10] The problem arises if leftward and rightward spreading of the same feature are subject to different blocking conditions. E.g., suppose a language has spreading in both directions, but leftward spreading is blocked by liquids and rightward spreading is not: /arawamawara/ → *arãw̃ãmãw̃ãr̃ã*. This result cannot be obtained with the current constraint-set because rightward spreading requires the ranking ⟦*A-SPAN(nasal) >> LIQHDOR⟧, which favors **ãr̃ãw̃ãmãw̃ãr̃ã*, and none of the head-position constraints favors *arãw̃ãmãw̃ãr̃ã* over **ãr̃ãw̃ãmãw̃ãr̃ã*. It may be possible to address this problem by revising the theory of bidirectional spreading to allow for cephalopagus (shared-head) feet (cf. Hyde 2002), but the required revisions in the theory are too much to go into here.

3. Comparison with alternatives

The OT literature offers at least three main approaches to the pro-spreading markedness constraint: a local AGREE constraint, feature-driven markedness, ALIGN or SPREAD constraints, and a SPECIFY constraint. I will examine each of these ideas in turn.[11]

[10] I am grateful to Shigeto Kawahara for raising this issue.

[11] Boersma (1998: 448-9, 2003) and Flemming (1995) propose theories of harmony based on constraints like Boersma's MAXDURATION(nasal), which favors candidates where the nasality percept is maximally enhanced durationally. Apart from the formal difficulties of defining an OT constraint with this effect, it makes an unlikely typological prediction

3.1 Local AGREE

The constraint AGREE is perhaps closest conceptually to iterative rules like (1). AGREE(αF) and similar constraints say that, if a segment bears the feature-value [αF], then the immediately preceding/following segment must also bear [αF] (Bakovic 2000, Eisner 1999, Lombardi 1999, 2001, Pulleyblank 2004). The problem with AGREE is that it has a sour-grapes property: it will favor spreading that is fully successful, but it gives up on candidates with partial spreading (McCarthy 2003, Wilson 2003, 2004).[12]

To see the problem, assume that we have a constraint AGREE-R(+nasal) that is violated by any sequence of two segments, the first of which is [+nasal] and the second of which is [–nasal]. The higher-ranking markedness constraint against nasalized obstruents blocks it from total satisfaction, as shown in (17).

(17) AGREE-R(+nasal) in blocked nasal spreading

N pəŋawasa	*[+nas, –son]	AGREE-R(+nasal)
a. ☞ N pəŋawasa		*
b. N pəŋawasa		*
c. N pəŋawasa	*!	
d. N pəŋawasa		*

Though AGREE favors candidates with total spreading like (17c), it is of no use when total spreading is ruled out by a blocking constraint like *[–cons, +nas]. The problem is that the remaining candidates (17a, b, d) each contain exactly one nasal-oral sequence, so each incurs one violation of AGREE. Since faithfulness and other markedness constraints will wrongly favor the candidate with no spreading (17b), AGREE is unhelpful in this and other systems where spreading is sometimes

(Wilson 2003, 2004). If the constraint dominates DEP, it allows epenthesis as a way to achieve spreading, and the more epenthesis the better: from input /masa/, the compliant candidates in harmonic order are ... ≻ *mãʔĩʔĩʔĩʔĩsa* ≻ *mãʔĩʔĩʔĩsa* ≻ *mãʔĩʔĩsa* ≻ *mãʔĩsa* ≻ *mãsa*.

[12] I am indebted to Colin Wilson for an advance look at Wilson (2004), which presents an alternative theory of spreading that, like Span Theory, is intended to address the problems with other approaches to autosegmental spreading in OT.

blocked. Since partial spreading is a richly attested phenomenon, AGREE is at best an inadequate foundation for a theory of autosegmental spreading in OT.[13]

Span Theory does not share this problem. AGREE fails because it is unable to distinguish between partial spreading and no spreading, since e.g. *mãw̃ãsa* and **mawasa* both contain a single [+nasal][–nasal] sequence. Span Theory, however, is able to distinguish between these two candidates and, indeed, between *mãw̃ãsa* and any other candidate with less complete spreading of nasality. The range of relevant candidates is explored in (18).

(18) Candidates with partial spreading

	/mawasa/	FRICHDOR	*A-SPAN(nasal)	GLIHDOR	VOWHDOR
a.	☞ (<u>m</u>awa)(<u>s</u>a)		*	*	***
b.	(<u>m</u>)(<u>a</u>)(<u>w</u>)(<u>a</u>)(<u>s</u>)(<u>a</u>)		*****!		
c.	(<u>m</u>)(<u>a</u>)(<u>w</u>a)(<u>s</u>a)		***!		**
d.	(<u>m</u>a)(<u>w</u>a)(<u>s</u>a)		**!		***
e.	(<u>m</u>a)(<u>w</u>asa)	*!	*		***
f.	(<u>m</u>aw)(<u>a</u>sa)	*!	*	*	**
g.	(<u>m</u>aw)(<u>a</u>)(<u>s</u>a)		**!	*	**

Partial spreading is favored because it absorbs segments that would otherwise have to head their own spans, thereby contributing more violations of *A-SPAN, as in (18b, c, d, e). The only candidates where *A-SPAN is not decisive are (18e, f), but they are ruled out by FRICHDOR — that is, they contain a blocking segment that is not the head of an oral span.

It is in principle possible to solve the problem of partial spreading with a modified AGREE constraint. Suppose AGREE mentions any necessary characteristics of the segment that is being spread onto, much like the iterative rule in (1). For Johore Malay, one could invent a constraint that is violated only by a sequence of a nasal segment immediately followed by an oral vocoid: *[+nasal][–cons, –nasal].

This analytic strategy really seems to miss the point of OT (Wilson 2003, 2004). The fundamental descriptive goals of OT are to derive complex patterns from the interaction of simple constraints and to derive language typology by permuting rankings. If AGREE is defined as *[+nasal][–cons, –nasal], then we are deriving a more complex pattern by complicating a constraint and not by interaction. More importantly, between-language differences in which segments are blockers (see (7, 8)) are obtained in this approach by proliferating AGREE constraints — *[+nasal][–cons, –nasal], *[+nasal][–son, +nasal], ... — and not by ranking permutation. The move of redefining AGREE to incorporate the blocking conditions, while technically possible, is antithetical to sound explanation.

[13] Wilson (2004) shows that the directional-evaluation theory of spreading (Eisner 1999: 20ff.) has the same sour-grapes property as AGREE.

3.2 Feature-driven markedness

Beckman (1997, 1998) presents another theory of autosegmental spreading in OT: feature-driven markedness (also see Alderete *et al.* 1999, Ito and Mester 1994, McCarthy and Prince 1994, Padgett 1995a, 1995b, Walker 1998a). The idea is that markedness constraints against individual autosegmental feature specifications — *[+nasal], *[–nasal] — assess candidates according to how many featural autosegments they contain and not according to the number of segments that bear the feature. On this assumption, *mãw̃ãs̃ã* incurs one violation of *[+nasal], while *mawasa*, *mãw̃ãsa*, etc. each have one violation of *[+nasal] *and* one violation of *[–nasal]. This means that feature-driven markedness, like AGREE, favors candidates with total spreading, but it cannot distinguish among candidates with different degrees of partial spreading.[14]

Span Theory's crucial differences from feature-driven markedness are the assumption that spans are headed and the concomitant constraints like (8) that require certain segment types to be heads. The impetus for spreading is a kind of economy of spans, *A-SPAN, rather than economy of autosegmental features.

3.3 ALIGN and SPREAD

3.3.1 Introduction. In Archangeli and Pulleyblank (1994b), Cole and Kisseberth (1995a), Kirchner (1993), Pulleyblank (1996), Smolensky (1993), and much other work, autosegmental spreading is compelled by gradient alignment constraints (McCarthy and Prince 1993). In Johore Malay, for example, the gradient constraint ALIGN([+nasal], R, Wd, R) ensures that each instance of the feature value [+nasal] maximizes its rightward spreading domain by counting the unassociated segments that follow it, as shown in (19).

(19) Gradient ALIGN([+nasal], R, Wd, R) in nasal spreading

N pəŋawasa	*[+nas, –son]	ALIGN(N, R, Wd, R)
a. ☞ N pəŋawasa		**
b. N pəŋawasa		*****!
c. N pəŋawasa	*!	
d. N pəŋawasa		****!

[14]See Bakovic (2000: 287ff.) for further discussion of feature-driven markedness and harmony.

Gradient ALIGN imposes a total ordering on the candidates in (19) (and others): *pəŋãw̃ãs̃ã* (19c) ≻ **pəŋãw̃ãsa* (19a) ≻ **pəŋãwasa* (19d) ≻ **pəŋawasa* (19b). The candidate that is topmost in this ordering has total spreading, but it is ruled out by the higher-ranking constraint *[+nas, –son], which thereby has the effect of blocking spreading through *s*. The laurels therefore go to the next candidate in the ordering, *pəŋãw̃ãsa* (19a), where [nasal] has spread as far as it can while still obeying *[+nas, –son].

This application of gradient alignment shares various conceptual problems with other gradient constraints (McCarthy 2003). More striking, though, is the extent to which gradient alignment makes implausible typological predictions. Because alignment seeks to minimize the number of unspread-to segments, ranking permutation allows it to produce results that differ wildly from spreading. Many of these pathological predictions have been identified by Wilson (2003, 2004); the following subsections describe his examples and a few others.

3.3.2 Harmony by blocked epenthesis (example adapted from Wilson). Imagine a language with vowel epenthesis to relieve codas: /kawas/ → *kawasi*. With the ranking in (20), ALIGN-R(nasal) can block epenthesis if a nasal consonant and intervening blocker precede at any distance in the word: /mawas/ → *mãw̃ãs*, **mãw̃ãsə.*

(20) Effect of *[+nas, –son] >> ALIGN-R(nasal) >> NO-CODA >> DEP-V

	*[+nas, –son]	ALIGN-R(nasal)	NO-CODA	DEP-V
/kawas/				
a. ☞ kawasə				*
b. kawas			*!	
/mawas/				
d. ☞ mãw̃ãs		*	*	
e. mãw̃ãs̃ə̃	*!			*
f. mãw̃ãsə		**!		*

This is a strange prediction: in reality, no known language allows the presence of a distant harmony trigger and intervening blocker to determine whether epenthesis occurs. The problem is that gradient alignment disfavors unspread-to segments. Spreading obviously decreases their numbers, but when spreading is blocked by a constraint like *[+nas, –son], ALIGN-R(nasal) is still potentially active since it also disfavors any *increase* in the number of unspread-to segments.

Span Theory does not predict this result. In Johore Malay-type systems, the number of adjacent spans in the word is not affected by vowel epenthesis, so ranking *A-SPAN(nasal) above NO-CODA does not change the outcome (see (21)).

(21) No blocking of epenthesis with *A-SPAN >> NO-CODA

/mawas/	FRICHDOR	*A-SPAN(nasal)	NO-CODA	GLIHDOR	DEP	VOWHDOR
a. ☞ (m̲awa)(s̲ə)		*		*	*	***
b. (m̲awa)(s̲)		*	*!	*		**
c. (m̲awasə)	*!					***

The intended winner (21a) and its primary competitor (21b) have identical numbers of adjacent spans, so they tie on *A-SPAN. In consequence, NO-CODA is able to do its job of ruling out *mãw̃ãs*.

Some of the constraints in Span Theory can block epenthesis under certain rankings, but they have this effect regardless of whether or not there is a preceding harmony trigger and blocker. If VOWHDOR dominates *A-SPAN(nasal), epenthesizing a vowel will add a span to a word, thereby adding a violation of *A-SPAN. But the effect is the same on, say, /mas/ and /pas/: (m̲)(a̲)(s̲)(ə̲) and (p̲)(a̲)(s̲)(ə̲) each have one more span than their faithful competitors (m̲)(a̲)(s̲) and (p̲)(a̲)(s̲). Therefore, the ranking ⟦VOWHDOR >> *A-SPAN(nasal) >> DEP-V >> NO-CODA⟧ simply prohibits vowel epenthesis; its effect on codas is equivalent to ranking NO-CODA above DEP-V. This is not a typological pathology — it's just an unexpected way of getting to a language that the theory already has. Similarly, it is possible to use the head location constraints to favor the span *(s̲)* over *(s̲ə)*, but again the effect is the same with /mas/ and /pas/. No pathology here either.

A similar argument can be made with consonant epenthesis.[15] By ranking ALIGN-R(nasal) above ONSET in a Johore Malay-type system, it is possible to get a language that forbids epenthesis of a consonant that threatens to block nasal spreading: /kawa-i/ → *kawati* vs. /mawa-i/ → *mãw̃ã.ĩ*, **mãw̃ãti*. Span Theory does not predict this unattested pattern because epenthesizing a blocking consonant affects the span structure of oral and nasal words equally: *(k̲awa.i)* vs. *(k̲awa)(t̲i)*, *(m̲awa.i)* vs. *(m̲awa)(t̲i)*.

3.3.3 Harmony by selection of short allomorphs (example adapted from Wilson). Under the assumption that allomorphs are lexically listed (for references, see McCarthy 2002: 183), allomorph selection is done entirely by markedness constraints because all allomorphs are equally faithful, *ceteris paribus*. Featural ALIGN constraints can favor selection of short allomorphs in contexts where harmony is blocked.

Imagine a language with Estonian-style allomorph selection (cf. Kager 1996): a suffix has the form *-ta* when the preceding syllable is unstressed and *-pta* when the preceding syllable is stressed: *ˈpasa-ta*, *ˈgabaˌsa-pta*. The markedness constraints WSP 'if heavy, then stressed' and SWP 'if stressed, then heavy' (cf. Prince 1990) will choose between the allomorphs, favoring light unstressed syllables (*ˈpa.sa.ta* ≻ **ˈpa.sap.ta*) and heavy stressed syllables (*ˈga.ba.ˌsap.ta* ≻ **ˈga.ba.ˌsa.ta*). The pathology comes from ranking ALIGN-R(nasal) above SWP: this disfavors the longer *-pta* allomorph only in words that contain a nasal consonant followed by a blocker. Tableau (22) illustrates the issue, assuming alternating stress on odd syllables and Johore Malay-style blocking.

[15] Thanks to Cheryl Zoll for pointing this out.

(22) Effect of ALIGN-R(nasal) >> SWP

/mawasa-{ta, pta}/	ALIGN-R(nasal)	SWP
a. ☞ ˈmã.w̃ã.ˌsa.ta	****	**
b. ˈmã.w̃ã.ˌsap.ta	*****!	*

No known language works like this, selecting allomorphs by prosodic criteria except in words with blocked harmony. Harmony processes can affect allomorph selection, but only with respect to the harmonizing feature, not with respect to size. Furthermore, this example has a highly nonlocal character that we do not usually observe in phonological processes: any preceding nasal segment and blocker, no matter how distant, is enough to trigger the shorter allomorph.

Span Theory does not make this unwanted prediction. The reason is that the choice of allomorphs has the same effect on span structure regardless of whether a nasal precedes or not. With OBSTHDOR and FRICHDOR ranked above *A-SPAN(nasal), the suffix allomorph *-pta* adds two spans to any stem, regardless of whether it contains a nasal or not:

(23) *A-SPAN(nasal) and allomorph selection

	*A-SPAN(nasal)
a. (ˈmawa)(ˌsa)(p)(ta)	***
b. (ˈmawa)(ˌsa)(ta)	**
c. (ˈga)(ba)(ˌsa)(p)(ta)	****
d. (ˈga)(ba)(ˌsa)(ta)	***

Choosing the short allomorph has the same effect in words with and without nasals: it avoids one span. This means that Span Theory cannot reproduce the unattested pattern predicted by ALIGN: selection of the short allomorph in words with blocked nasal harmony.

Because /-pta/ contains two blocking segments while /-ta/ contains just one, the longer allomorph always adds one more *A-SPAN violation than the shorter violation. Therefore, by ranking *A-SPAN above SWP, it is possible to favor the shorter allomorph in all words (and crucially not just words that contain nasal consonants). This is not an instance of the pathological pattern; in fact, it's just an obscure way of saying that the language has no size-based allomorphy. Languages without such allomorphy are attested, of course.

Wilson observes that the allomorph-selection problem with ALIGN is particularly important because it does not involve faithfulness. Similar typological problems ('too many repairs') have sometimes been addressed by imposing fixed rankings between markedness and faithfulness constraints (Pater 2003) or among faithfulness constraints (Steriade 2001). But allomorph selection is not usually a matter of faithfulness since both allomorphs are already present in the input. Therefore, a solution involving fixed ranking would involve requiring ALIGN(F) to be dominated by all markedness constraints that might conceivably affect affix-size allomorphy. Obviously, such an approach would have a highly arbitrary cast.

3.3.4 Harmony by alteration of blockers. Another way to improve alignment is to change the manner features of a potential blocker so that it can harmonize and thereby cease to be a blocker. For example, in a language where liquids but not fricatives can nasalize (see (7) and the nearby text), the mapping /mawasa/ → *m̃ãw̃ãr̃ã* will be favored if ALIGN([+nasal], R, Wd, R) dominates IDENT(sonorant). To be perfectly clear, this hypothetical language would change /s/ to *r* only when the result is improved nasal harmony. There would be no change in words that lack nasals or where harmony is already blocked: /gabasa/ → *gabasa*, **gabara*; /nadasa/ → *nãdasa*, **nãdara*.

This does not seem to happen. Although there are certainly languages with rhotacism and other lenition processes, lenition probably never occurs solely to improve nasal harmony, nor are similar processes found with other types of harmony.[16] Span Theory does not predict this pattern because the effect of lenition on satisfaction of *A-SPAN(nasal) is independent of nasal harmony. In a language like Kolokuma Ijo where liquids are the least sonorous segments that can become nasalized, *A-SPAN(nasal) must be ranked below FRICHDOR and above LIQHDOR (see (8)). Changing an /s/ to an *r* will improve performance on *A-SPAN(nasal), but it will do so equally in contexts with and without nasal harmony, as shown in (24).

(24) *A-SPAN(nasal) and lenition

		*A-SPAN(nasal)
/mawasa/		
a.	(<u>m</u>awa)(<u>s</u>a)	*
b.	(<u>m</u>awara)	
/gabasa/		
c.	(<u>g</u>a)(<u>b</u>a)(<u>s</u>a)	**
d.	(<u>g</u>a)(<u>b</u>ara)	*
/nadasa/		
e.	(<u>n</u>a)(<u>d</u>a)(<u>s</u>a)	**
f.	(<u>n</u>a)(<u>d</u>ara)	*

Replacing /s/ with *r* has the same effect on satisfaction of *A-SPAN(nasal) in nasal and oral contexts. This means that Span Theory is unable to reproduce the unattested pattern predicted by ALIGN: lenition solely to improve nasal spreading.

In a language with left-headed nasal spans, the ranking ⟦FRICHDOR >> *A-SPAN(nasal) >> IDENT(sonorant)⟧ will produce lenition of *all* non-initial stops and fricatives, however. Although it may be odd to think of *A-SPAN as motivating lenition, the resulting system is not implausible

[16] A seeming counterexample comes from tone spreading in Wuyi (Bao 1990, Duanmu 1990, Yip 1995). (Thanks to Maria Gouskova for pointing this out.) According to Yip, when high register spreads from one syllable to the next, an intervening voiced obstruent becomes voiceless. This is not analogous to the situation described in the text, however. In Yip's analysis, devoicing is not merely facilitating high register spread; rather, high register and voicelessness are the same feature, so devoicing quite literally *is* high register spread.

typologically. In fact, any worked-out theory of lenition, such as Kirchner (1998), is sure to make the same prediction: word-initial position is typically the locus of fortition, not lenition (Kirchner p. 10); and low-sonority segments are typically more susceptible to lenition than high-sonority segments. Furthermore, the neutralization of contrast in all positions except initial is predicted by positional faithfulness theory (Beckman 1997, 1999). In short, this prediction of Span Theory is already with us anyway.

3.3.5 Harmony by deletion. Gradient alignment can compel deletion of segments that are inaccessible to spreading: /mawasa/ → *mãw̃ã*. All that is required is for MAX to be dominated by ALIGN and some of the nasal incompatibility constraints in (7). Tableau (25) illustrates.

(25) Effect of ALIGN-R(nasal) >> MAX

/mawasa/	*[+nas, –son]	ALIGN-R(nasal)	MAX
a. ☞ mãw̃ã			**
b. mãw̃ãsa		**!	
c. mãw̃ãs̃ã	*!		

Another possible outcome is *mãw̃ã.ã*, with deletion of only /s/. Whether this form or (25a) *mãw̃ã* wins is determined by constraints like ONSET and I-CONTIG.[17] In general, the ⟦ALIGN-R >> MAX⟧ ranking is capable of enforcing nasal harmony by deleting all blocking segments that follow the nasal trigger or by deleting everything from the first blocking segment after the nasal trigger up to the end of the word. Needless to say, no known language achieves total spreading by this sort of deletion.

Span Theory makes no such prediction. Performance on *A-SPAN(nasal) can be improved by deletion, but the effect is the same whether or not the word contains a nasal trigger and blocker. This is shown in (26).

[17] I-CONTIG (Kenstowicz 1994, McCarthy and Prince 1995, 1999) prohibits non-peripheral deletion by requiring the input segments that have output correspondents to form a contiguous string.

(26) *A-SPAN(nasal) and deletion

	*A-SPAN(nasal)
/mawasa/	
a. (mawa)	
b. (mawa)(sa)	*
c. (mawa.a)	
/gawasa/	
d. (gawa)	
e. (gawa)(sa)	*
f. (gawa.a)	

Deletion of a blocking segment eliminates a span; it doesn't matter whether the preceding span is nasal or oral. Therefore, Span Theory cannot reproduce the unattested pattern where nasal harmony induces deletion of blocking segments and possibly other segments beyond them.

3.3.6 Harmony by reduplicative emergence of the unmarked (example adapted from Wilson). This argument is similar to the one in the preceding section. Markedness constraints can affect reduplicative copying in a phenomenon known as reduplicative emergence of the unmarked (McCarthy and Prince 1994). If it is ranked above MAX-BR, gradient ALIGN(nasal) can determine how much is copied , favoring less copying in regions that are inaccessible to spreading. Tableau (27) shows this unwanted result in a language with Johore Malay-type harmony.

(27) Effect of ALIGN-R(nasal) >> MAX-BR

	ALIGN-R(nasal)	MAX-BR
/mapata+RED/		
a. ☞mãpata-ta	******	****
b. mãpata-pata	********!	**
/gadaba+RED/		
c. gadaba-ba		****!
d. ☞gadaba-daba		**

We can assume that other constraints rule out total copying and non-copying as alternatives to (27d) and (27a), respectively.

Span Theory does not make this unwanted prediction. The reasoning is very similar to the preceding section: copying has the same effect on the span structure of /mapata/ and /gadaba/, as shown in (28).

(28) *A-SPAN(nasal) and copying

	*A-SPAN(nasal)
/mapata+RED/	
a. (mã)(pa)(ta)(ta)	***
b. (mã)(pa)(ta)(pa)(ta)	****
/gadaba+RED/	
c. (ga)(da)(ba)(ba)	***
d. (ga)(da)(ba)(da)(ba)	****

This means that *A-SPAN(nasal) can affect the size of the reduplicant — as indeed many other markedness constraints can. But it cannot produce the odd nonlocal dependency seen in (27), where the presence of a nasal anywhere earlier in the word can shrink the reduplicant.

3.3.7 Harmony by affix repositioning (example adapted from Wilson). By dominating affixal alignment constraints, markedness constraints can compel infixation (Prince and Smolensky 1991, 2004 and others).[18] They can even cause affixes to switch between prefixal and suffixal position (Fulmer 1997, Noyer 1993). Gradient ALIGN(nasal) can affect affix placement, as shown in (29).

(29) Effect of ALIGN-R(nasal) >> ALIGN-R(suffix)

	ALIGN-R(nasal)	ALIGN-R(suffix)
/mapata+ka/		
a. ☞ka-mãpata	****	******
b. mãpata-ka	******!	
/gadaba+ka/		
c. ka-gadaba		******!
d. ☞gadaba-ka		

In this language, /-ka/ is suffixed unless the stem contains a nasal, in which case /-ka/ is prefixed. In known cases of infixation and prefix/suffix alternation, local phonological conditions are decisive; the quality of a distant segment has never been observed to have such an effect.

*A-SPAN(nasal) cannot produce this alternation. The reasoning should by now be familiar: *A-SPAN(nasal) has similar effects on the span structure of oral and nasal words, as shown in tableau (30).

[18] Though see Horwood (to appear) and Yu (2003) for other views.

(30) *A-SPAN(nasal) and affix position

		*A-SPAN(nasal)
a.	(ka)-(mã)(pa)(ta)	***
b.	(mã)(pa)(ta)-(ka)	***
c.	(ka)-(ga)(da)(ba)	***
d.	(ga)(da)(ba)-(ka)	***

Obviously, the competing candidates have equal numbers of [nasal] spans, so *A-SPAN(nasal) is unable to affect the position of the affix.

To certify this typological result, we also need to look at affixes that do not contain blocking segments. For instance, if the affix is /-wa/ in a Johore Malay-type system, what is the effect of *A-SPAN(nasal)? The answer again is none: because *A-SPAN(nasal) dominates GLIHDOR, suffixed /-wa/ will simply attach itself to the nasal or oral span that ends the preceding stem.

3.3.8 Harmony by stress shift (example adapted from Wilson). In Guaraní, stressed syllables block nasal harmony. Beckman (1999) attributes this to the positional faithfulness constraint IDENT$_{\acute{\sigma}}$(nasal), which prevents stressed vowels from changing between nasal and oral. Assume a language with regular penultimate stress in satisfaction of NONFINALITY. By ranking IDENT$_{\acute{\sigma}}$(nasal) and ALIGN-R(nasal) above NONFINALITY, it's possible to force stress to shift in order to increase the extent of nasal spreading. Tableau (31) shows why.

(31) Effect of IDENT$_{\acute{\sigma}}$(nasal) >> ALIGN-R(nasal) >> NONFINALITY

		IDENT$_{\acute{\sigma}}$(nasal)	ALIGN-R(nasal)	NONFINALITY
	/mawata/			
a.	☞ mãw̃ãtá		**	*
b.	mãwáta		****!	
c.	mãw̃ã́ta	*!	**	
	/gawata/			
c.	gawatá			*!
d.	☞gawáta			

Regular penultimate stress shows up if there is no preceding nasal; the peculiarity is the final stress that is forced by the desire to improve nasal alignment.

This pathology exposes a problem with positional faithfulness as much as or more than a problem with ALIGN(F). In non-pathological applications of positional faithfulness, the position of special faithfulness (e.g., penultimate stress) is taken to be a given, constant across the candidates of interest. But Beckman (1999) and Wilson (2000, 2001) show that there are rankings where positional faithfulness can affect where the position of special faithfulness is located. For instance, if a language has a process raising /a/ to *i* in open syllables, then the positional faithfulness constraint IDENT$_{\acute{\sigma}}$(height) can force stress off an open syllable that contains underlying /a/. For example, even if the language normally has initial stress, this interaction will favor /pati/ → *pití* over **píti* (cf. /piti/ → *píti* in the same language). This hypothetical and presumably impossible example reveals a weakness in positional faithfulness theory that's independent of alignment.

In any case, Span Theory does not predict the result in (31). To understand why, we need to look closely at the faithfulness constraint FTHHDSP(αF) (5). This constraint is satisfied when input [αF] segments are matched with output segments that are the heads of [αF] spans. The positional faithfulness version of this constraint, FTHHDSP$_{\acute{\sigma}}$(αF), imposes the same requirement, but only on the segments in (output) stressed syllables. In Guaraní, because stressed syllables block harmony, FTHHDSP$_{\acute{\sigma}}$(–nasal) must dominate *A-SPAN(nasal). The effect of this ranking is the same regardless of whether a nasal precedes, as shown in (32).

(32) ⟦FTHHDSP$_{\acute{\sigma}}$(–nasal) >> *A-SPAN(nasal), NONFINALITY⟧

	FTHHDSP$_{\acute{\sigma}}$(–nasal)	*A-SPAN(nasal)	NONFINALITY
/mawata/			
a. (m̲awa)(t̲á)		*	*
b. (m̲a)(w̲á)(t̲a)		**	
c. (m̲awá)(t̲a)	*!		
/gawata/			
d. (g̲awa)(t̲á)		*	*
e. (g̲a)(w̲á)(t̲a)		**	
f. (g̲awá)(t̲a)	*!	*	

FTHHDSP$_{\acute{\sigma}}$(–nasal) rules out nasal spreading onto a stressed syllable, as in (32c). It also rules out vacuous spreading of oral onto a stressed syllable, as in (32f). The ranking of *A-SPAN(nasal) and NONFINALITY determines whether stress falls on the penult or ultima, but the effect is the same regardless of whether there is a preceding nasal or oral span.

This example requires that FTHHDSP be defined in terms of span heads, as in (5). The stressed syllable *wá* of (32f) is faithful, IDENT-wise, but unfaithful, FTHHDSP-wise. The same syllable is unfaithful in (32c) under either formulation of faithfulness. To avoid the pathology, it's important that FTHHDSP be used and not IDENT. With IDENT, we get stress shift only to facilitate spreading of [+nasal] — an unattested pattern. With FTHHDSP, stress will shift either across the board or not at all.

3.3.9 SPREAD. Nearly all of ALIGN's typological problems are duplicated with the non-local SPREAD constraint and its variously-named counterparts (Kaun 1995: 98, Myers 1997: 861-3, Padgett 1995a, Rose and Walker 2001, Walker 1998b). SPREAD(F) says that, for every instance of the feature value F in a form, assign a violation-mark for every segment not associated with that feature value. SPREAD is, in effect, a nondirectional version of gradient ALIGN: it favors reducing the number of segments that have not been spread onto, including those that are inaccessible to spreading. Just like ALIGN, SPREAD(+nasal) could in principle be satisfied by deletion, blocking of epenthesis, allomorph selection, etc., all of which are available via ranking permutation. Since such phenomena are unattested, the SPREAD constraint is in the same pickle as ALIGN.

3.4 SPECIFY

Myers (1997: 861) and Zoll (2003: 241) analyze tone spreading as a consequence of a constraint against epenthesizing tones (DEP(T)) and a constraint requiring every syllable to have a tone (SPECIFY(T)). If a syllable has no input tone, if it must gain an output tone because of SPECIFY(T), and if it is denied an epenthetic tone because of DEP(T), then it will receive a tone by spreading from a nearby syllable.

This approach encounters the same problems as ALIGN and SPREAD. Toneless syllables will incur the same marks from SPECIFY(T) as they do from SPREAD(T). Therefore, SPECIFY makes the same unwanted predictions when tone spreading is blocked (e.g., by a depressor consonant): deletion of syllables that are inaccessible to tone spreading, blocking of epenthesis in regions that are inaccessible to tone spreading, and selection of shorter allomorphs in inaccessible regions.

This approach has a further problem when it is applied to spreading of non-tonal features. In tone, it presupposes that there are toneless syllables, and indeed that tone spreads only onto toneless syllables. Therefore, for non-tonal features, it requires privative feature representations, [nasal] vs. Ø rather than [+nasal] vs. [–nasal]. But this means that SPECIFY([nasal]) is perfectly satisfied only if every segment is nasal. With the ranking ⟦SPECIFY([nasal]) >> DEP([nasal])⟧, we get a language in which there are no oral segments whatsoever — a complete inversion of the actual markedness situation.

3.5 Summary

We have seen that there are two main reasons why various proposals for the pro-spreading constraint fail. It is possible to distinguish among candidates with partial spreading, but only at the cost of predicting the existence of languages where ‘spreading’ is achieved by segmental deletion, blocking epenthesis, selection of short allomorphs, or processes like lenition. It is also possible to avoid these unwanted predictions, but only at the cost of failing to distinguish among candidates with different degrees of partial spreading.

4. Conclusion

In this article, I have argued for Span Theory, a modification of autosegmental phonology in OT. Span Theory requires relatively modest revisions in GEN and CON.[19] On the GEN side, segments are exhaustively parsed into spans for a given feature [F]. Each [F] span has a unique segmental head, and the head’s value for [F] determines the pronunciation of the whole span. On the CON side, *A-SPAN(F) prohibits adjacent spans, and it is opposed by faithfulness and markedness

[19]Revisions to GEN and CON are routine in current phonological research. For example, adopting a different phonological representation is implicitly a change in GEN, while proposing or modifying a constraint is explicitly a change in CON.

constraints that require certain segments to head spans. Interaction between *A-SPAN and these other constraints is the source of spreading and blocking patterns in language.

The goal of Span Theory is to address a serious gap in most current theorizing about autosegmentalism in OT: the lack of a satisfactory constraint to compel autosegmental spreading. By modifying autosegmental representations and their attendant constraints in the way I have proposed, most if not all of the problems with other approaches to spreading are eliminated.

Of course, the literature on autosegmental phonology and its applications and variations is vast, and no work like this could possibly do more than touch on it. Nonetheless, I hope to have been able at least to suggest how Span Theory addresses the most common autosegmental phenomena.

Appendix: Potential effects of span-head location constraints

See section 2.6 for discussion of this table.

		GLIHDOR	*A-SPAN (nasal)	SPHDL (+nasal)	SPHDR (+nasal)	SPHDL (–nasal)	SPHDR (–nasal)
1.	(a)(w)(a)(m)(a)(w)(a)		6				
2.	(a)(w)(a)(m)(a)(wa)		5				1
3.	(a)(w)(a)(m)(aw)(a)		5			1	
4.	(a)(w)(a)(m)(awa)		4			1	1
5.	(a)(w)(a)(ma)(w)(a)		5		1		
6.	(a)(w)(a)(ma)(wa)		4		1		1
7.	(a)(w)(a)(maw)(a)	1	4		1		
8.	(a)(w)(a)(mawa)	1	3		1		
9.	(a)(w)(am)(a)(w)(a)		5	1			
10.	(a)(w)(am)(a)(wa)		4	1			1
11.	(a)(w)(am)(aw)(a)		4	1		1	
12.	(a)(w)(am)(awa)		3	1		1	1
13.	(a)(w)(ama)(w)(a)		4	1	1		
14.	(a)(w)(ama)(wa)		3	1	1		1
15.	(a)(w)(amaw)(a)	1	3	1	1		
16.	(a)(w)(amawa)	1	2	1	1		
17.	(a)(wa)(m)(a)(w)(a)		5				1
18.	(a)(wa)(m)(a)(wa)		4				2
19.	(a)(wa)(m)(aw)(a)		4			1	1
20.	(a)(wa)(m)(awa)		3			1	2

		GliHdOr	*A-Span (nasal)	SpHdL (+nasal)	SpHdR (+nasal)	SpHdL (–nasal)	SpHdR (–nasal)
21.	(a)(wa)(ma)(w)(a)		4		1		1
22.	(a)(wa)(ma)(wa)		3		1		2
23.	(a)(wa)(maw)(a)	1	3		1		1
24.	(a)(wa)(mawa)	1	2		1		1
25.	(a)(wam)(a)(w)(a)	1	4	1			
26.	(a)(wam)(a)(wa)	1	3	1			1
27.	(a)(wam)(aw)(a)	1	3	1		1	
28.	(a)(wam)(awa)	1	2	1		1	1
29.	(a)(wama)(w)(a)	1	4	1	1		
30.	(a)(wama)(wa)	1	2	1	1		1
31.	(a)(wamaw)(a)	2	2	1	1		
32.	(a)(wamawa)	2	1	1	1		
33.	(aw)(a)(m)(a)(w)(a)		5			1	
34.	(aw)(a)(m)(a)(wa)		4			1	1
35.	(aw)(a)(m)(aw)(a)		4			2	
36.	(aw)(a)(m)(awa)		3			2	1
37.	(aw)(a)(ma)(w)(a)		4		1	1	
38.	(aw)(a)(ma)(wa)		3		1	1	1
39.	(aw)(a)(maw)(a)	1	3		1	1	
40.	(aw)(a)(mawa)	1	2		1	1	
41.	(aw)(am)(a)(w)(a)		4	1		1	
42.	(aw)(am)(a)(wa)		3	1		1	1
43.	(aw)(am)(aw)(a)		3	1		2	
44.	(aw)(am)(awa)		2	1		2	1
45.	(aw)(ama)(w)(a)		3	1	1	1	
46.	(aw)(ama)(wa)		2	1	1	1	1
47.	(aw)(amaw)(a)	1	2	1	1	1	
48.	(aw)(amawa)	1	1	1	1	1	
49.	(awa)(m)(a)(w)(a)		4			1	1
50.	(awa)(m)(a)(wa)		3			1	2
51.	(awa)(m)(aw)(a)		3			2	1

		GliHdOr	*A-Span (nasal)	SpHdL (+nasal)	SpHdR (+nasal)	SpHdL (–nasal)	SpHdR (–nasal)
52.	(awa)(m)(awa)		2			2	2
53.	(awa)(ma)(w)(a)		3		1	1	1
54.	(awa)(ma)(wa)		2		1	1	2
55.	(awa)(maw)(a)	1	2		1	1	1
56.	(awa)(mawa)	1	1		1	1	1
57.	(awam)(a)(w)(a)	1	3	1			
58.	(awam)(a)(wa)	1	2	1			1
59.	(awam)(aw)(a)	1	2	1		1	
60.	(awam)(awa)	1	1	1		1	1
61.	(awama)(w)(a)	1	2	1	1		
62.	(awama)(wa)	1	1	1	1		1
63.	(awamaw)(a)	2	1	1	1		
64.	(awamawa)	2		1	1		

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