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Transparency in Span Theory

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1. Introduction*

This paper presents a new approach to the representation of transparency in vowel harmony, adapting the Span Theory analysis of featural association (McCarthy 2004). Transparent segments appear within the domain of harmony but fail to take on the harmonic feature. Unlike opaque segments which block spreading, however, transparent segments do not interfere; they allow segments which follow them to take on the harmonic feature.

An example of transparency can be found in Wolof (Ka 1994), a Senegambian language spoken in Senegal. Wolof has tongue root harmony, but high vowels may only be +ATR. In most cases, the ATR value of the stem spreads to the suffix vowels:

(1) a. √now-leːn 'come!'
come-2PLIMP
b. √tɔgg-lɛːn 'cook!'
cook-2PLIMP

However, high vowels are transparent to this process; if a high vowel intervenes between two non-high vowels, it will have no effect on harmony. In the following examples, the mid vowels of the suffix agree with the [–ATR] specification of the stem, despite the fact that a high [+ATR] vowel intervenes:

(2) a. √bɔkk-ulɛːn 'you are not part of'
be.part.of-2PLNEG
b. √sɛːt-ulɛːn 'you did not look at'
look.at-2PLNEG

Transparency has been problematic in a number of representational frameworks. In an autosegmental approach, it requires violation of "no crossing" restrictions. An example such as [bɔkkulɛɛn] would require the [–ATR] specification of [ɔ] to cross over the [+ATR] specification of [u]. Thus only opacity is predicted in vowel harmony

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systems (see Goad 1991 for an illustration of opacity in Akan, to be discussed in section 3). Similarly, in a framework using the AGREE constraint (e.g. Baković 2000, 2003), there is no provision for non-local agreement. The only available solutions in this system are derivationally opaque approaches such as targeted constraints (Baković and Wilson 2000) or sympathy theory (Walker 2003). The same problem arises in Span Theory (McCarthy 2004). Span Theory requires every segment in a domain to agree in the harmonizing feature, but although transparent vowels must be inside the span of harmony, they do not take on the feature of the span.

The proposal presented in this paper is that the requirement for all segments to agree in their value for the harmonizing feature is violable; that is, segments within the domain of harmony (in theoretical terms, a headed feature span) do not have to agree with the feature defining this domain. Thus this analysis requires the featural association aspect of span structure to be relocated from GEN to CON. Association with the head is motivated by constraints of the following form, where *F*, *G*, and *H* are features and *β* and *γ* are values:

(3) ASSOCIATEHEAD([βG, γH, …], [F]): Every [βG, γH, …] must share the value of the head of the F-span in which it is located.

This paper is organized as follows. Section 2 develops the ASSOCIATEHEAD approach to vowel transparency in Wolof. Section 3 examines theoretical predictions with regards to vowel opacity, using Akan as the language of investigation. Section 4 considers further typological implications of the theory. Section 5 frames the theory in qualitative terms and considers directions for future work.

2. Transparency in vowel harmony

This section proposes that association with the active feature in the domain of vowel harmony is the result of violable markedness constraints. Such a proposal enables McCarthy's (2004) Span Theory to provide a cohesive account of transparency.

The specific case under consideration will be that of Wolof ATR harmony (Ka 1994). Wolof has the following vowels:

(4) *Wolof vowel system*

	front	central	back	
	+ –	+ –	+ –	
	i		u	high
	e ɛ	ə a	o ɔ	non-high

Recall that, as shown in (1), affixes take on the ATR value of the stem; given an input /√now+lɛɛn/, the grammar will produce [nowleen]. Such a pattern can be readily formalized in Span Theory.

Span Theory is an association-based account of featural spreading in Optimality Theory (Prince and Smolensky 2004) with the following requirements in GEN:

(5) Words are exhaustively divided into spans corresponding to each distinctive feature.
(6) Every span for feature [F] has a head that determines the F-value of that span.

Thus [nowleːn] is given the Span Theory representation[1]:

(7) (n<u>o</u>wleːn)

The segment [<u>o</u>] is a span head, indicated typographically with underlining. Span boundaries are indicated by parentheses.

Span Theory makes use of three general classes of constraints:

(8) *A-SPAN(F): No adjacent F-spans / minimize F-spans. Assign one violation for every span in a candidate after the first.
(9) FAITHHEADSPAN(αF): If an input segment x_I has value [αF] and it has a correspondent output segment x_O, x_O will head a [αF] span.
(10) HEAD([βG, γH, …], [αF]): Every [βG, γH, …] heads a [αF] span.

The *A-SPAN class of constraints militates against heads; the candidate which best satisfies *A-SPAN(F) will be that in which the entire candidate is inside one span. The FAITHHEADSPAN(αF) class of constraints militates against loss of headedness. In other words, it is satisfied best by a candidate in which every input segment both keeps its value and heads a span of that value[2]. The HEAD([βG, γH, …], [αF]) class of constraints militates against certain feature values. It is satisfied best by a candidate in which every element of type [βG, γH, …] is the head of a [αF] span. Note that it is not in fact satisfied if these elements are simply inside spans of value [αF]. Thus Span Theory is really a theory of *spreading* and not simply of association; simply *having* a value is not a sufficient condition to satisfy either FAITHHEADSPAN or HEAD.

For Wolof ATR harmony, the following constraints are necessary:

(11) *A-SPAN(ATR): No adjacent ATR spans. Henceforth *A-SPAN.
(12) FAITHHEADSPAN(+ATR): If an input segment x_I has value [+ATR] and it has a correspondent output segment x_O, x_O will head a [+ATR] span.
(13) FAITHHEADSPAN(–ATR): If an input segment x_I has value [–ATR] and it has a correspondent output segment x_O, x_O will head a [–ATR] span.
(14) HEAD([–high], [+ATR]): Non-high vowels head +ATR spans.
(15) HEAD([–high], [–ATR]): Non-high vowels head –ATR spans.

[1] I am overtly marking the feature that spreads – McCarthy's notation would represent (7) as (n<u>o</u>wlɛːn) rather than (n<u>o</u>wleːn). My notation is chosen for ease of illustrating my argument. Both notations represent the domain of spreading, but McCarthy's original notation shows the underlying form, whereas my notation shows the surface form. This is to avoid confusion in representations containing non-associating elements.

[2] Note that FAITHHEADSPAN(αF) is really a conjunction of markedness (*head a span of value αF*) and faithfulness (*preserve values of F*).

In this case, (11) and (12) are formulated in terms of "non-high" vowels. These constraints can of course be broken down further into low and mid vowels (and in section 3 it will be shown that Akan ATR harmony requires specific reference to low vowels), but Wolof will never provide examples of conflict between these constraints. Thus it is a harmless simplification to treat these constraints as one for the purposes of this discussion.

Furthermore, observe that Wolof vowel harmony only affects affixes: underlying forms such as /√now+lɛːn/ surface as [nowleːn] and never *[nɔwlɛːn]. In other words, this pattern is an example of stem-controlled harmony (McCarthy and Prince 1995; Baković 2000, 2003). Thus it is necessary to adapt Baković's IDENT-SA constraint into Span Theory terms:

(16) FAITHSTEM(ATR): If an input segment x_I is in the stem, has value [αATR], and has a correspondent output segment x_O , x_O will head a [αATR] span.

Note, again, that this is really a spreading theory – stem elements must both maintain their value and span heading.

Now, given an input /√now+lɛːn/, the grammar can correctly select the optimum with the correct set of rankings. First, it is necessary that *A-SPAN can force violation of any constraints militating against spreading, namely the HEAD constraints:

(17) *Wolof ATR harmony: spreading forced by *A-SPAN*[3]

/√now + lɛːn/ → nowleːn	*A-SPAN	FAITHHEAD (–ATR)	HEAD([–high], [+ATR])	HEAD([–high], [–ATR])
a. (nowleːn) ~ (n*o*w)(lɛːn)	W $_{0\sim1}$	L $_{1\sim0}$	$_{1\sim1}$	L $_{2\sim1}$
b. (nowleːn) ~ (n*o*w)(leːn)	W $_{0\sim1}$	$_{1\sim1}$	L $_{1\sim0}$	$_{2\sim2}$

In (17a), the losing candidate exhibits no spreading of the +ATR feature. (17a) also indicates that *A-SPAN must outrank FAITHHEAD(–ATR), which is a logical consequence of the fact that here the +ATR feature spreads over –ATR. Note that both candidates in (17b) actually will be pronounced in the same way; the ranking of *A-SPAN over NLHD+ in this context can be thought of as analogous to the Obligatory Contour Principle in autosegmental phonology.

Second, since the +ATR feature spreads over –ATR, FAITHSTEM must force violation of both FAITHHEAD(–ATR) and HEAD([–high], [–ATR]):

[3] I will use comparative tableaux (Prince 2002a) throughout this paper. Each row of the tableau is presented as a comparison between candidates. The leftmost cell of each row is formatted as [winner]~[loser]. Each constraint evaluation is marked with W if it favors the *winner* and L if it favors the *loser*. The number of violations incurred by each candidate is indicated in a subscript (ordered winner~loser). For any comparison, some constraint evaluated W must outrank all constraints evaluated L.

(18) *Wolof ATR harmony: stem control forced by FAITHSTEM(ATR)*

/√now + lɛːn/ → nowleːn	FAITHSTEM (ATR)	FAITHHEAD (–ATR)	HEAD([–high], [–ATR])
a. (nowleːn) ~ (nɔwlɛːn)	W $_{0\sim1}$	L $_{1\sim0}$	L $_{2\sim1}$

Similar cases can be seen with an input such as /√tɔgg+leːn/. Here, however, the output will be [tɔgglɛːn], corresponding to spreading of –ATR over +ATR:

(19) *Wolof ATR harmony: spreading forced by *A-SPAN*

/√tɔg + leːn/ → tɔglɛːn	*A-SPAN	FAITHHEAD (+ATR)	HEAD([–high], [+ATR])
a. (tɔglɛːn) ~ (tɔg)(leːn)	W $_{0\sim1}$	L $_{1\sim0}$	L $_{2\sim1}$

(20) *Wolof ATR harmony: stem control forced by FAITHSTEM*

/√tɔg + leːn/ → tɔglɛːn	FAITHSTEM (ATR)	FAITHHEAD (+ATR)	HEAD([–high], [+ATR])
a. (tɔglɛːn) ~ (togleːn)	W $_{0\sim1}$	L $_{1\sim0}$	L $_{2\sim1}$

Fusion of the rankings from (17) through (20) yields a ranking for the Wolof ATR harmony cases shown above:

(21) *"Non-disharmonic" Wolof ATR harmony*:
{*A-SPAN, FAITHSTEM} >> {HEAD([–high],[+ATR]), HEAD([–high],[–ATR]),
FAITHHEAD(+ATR), FAITHHEAD(–ATR)}

In other words, *A-SPAN and FAITHSTEM outrank all other constraints, which is consistent with the observation that, in the data presented above, the stem determines the ATR values for the rest of the word, without restriction.

As shown in (2), the process of harmony skips over high vowels. However, high vowels cannot simply be treated as lacking ATR values, because high vowels trigger ATR spreading when they are in stems[4], as shown in (22a):

(22) a. √xul-oː 'to quarrel'
quarrel-RECIP
/√xul-ɔː/ → [xuloː]

b. √sɔng-ɔː 'to attack each other'
attack-RECIP
/√sɔng-ɔː/ → [sɔngɔː]

Example (22b) demonstrates harmonic behavior of the suffix following a –ATR vowel; (22a) shows [+ATR] spreading to the same suffix.

[4] Thanks to John Kingston for raising this issue.

Span Theory as originally formulated cannot account for this phenomenon; a segment must either be a head or be associated with a head. Obviously transparent high vowels cannot be associating with heads, as they would then show harmonic behavior. But neither can they be heads themselves, as this would predict opaque behavior. The proposal of this paper, then, is that span structure is not as rigid as stated in (6): while the head of a span determines the value of that span, association with the head is violable. Individual elements may disagree. Thus the cases in (2) can both be analyzed as single spans; [bɔkkulɛːn] simply has a non-associating element (bracketed):

(23) (bɔ̠kk[u]lɛːn)

Such structures not only capture the behavior of transparent vowels, but also allow theoretical accounts of harmony to cover a wider range of phenomena than is generally assumed.

To permit the structure in (23), some aspects of Span Theory must be moved from GEN to CON. Specifically, association with the head of a span needs to be violable. This will be accomplished with the following class of constraints:

(24) ASSOCIATEHEAD([βG, γH, …], [F]): Every [βG, γH, …] must share the value of the head of the F-span in which it is located.

Now consider the case of Wolof. For the sake of illustration, let us ignore consonants for the time being and simply consider an input /√ɔ.ue/, which will surface as [ɔuɛ]. Note, however, that this system includes no constraints that would actually preclude harmony of high vowels. Therefore it is necessary to introduce a markedness constraint, grounded in the observation that Wolof has no –ATR high vowels[5]:

(25) *[+high, –ATR]: +high and –ATR may not co-occur.

This constraint can easily be ranked over any constraints with which it may conflict; an input such as /ʊ/ will never surface faithfully. Furthermore, note that transparent cases in Wolof will always violate the following:

(26) ASSOCIATEHEAD([+high], [ATR]): Every high vowel must share the value of the head of the ATR-span in which it is located.

Of course, similar ASSOCIATEHEAD constraints for mid and low vowels and consonants exist somewhere in the grammar. However, as an optimal candidate will never violate the ASSOCIATEHEAD(mid, [ATR]) and ASSOCIATEHEAD(low, [ATR]) constraints, they can safely be omitted from consideration for the time being; omitting these constraints will allow the derivation a minimal ranking argument that directly illuminates the

[5] Archangeli and Pulleyblank (1994) point out that +high and +ATR generally have some affinity, which provides some general motivation for such constraints.

typological predictions of the theory (these issues will be discussed more directly in section 4).

Since there are no –ATR consonants in Wolof, the distribution of consonants with respect to vowel harmony will essentially match that of high vowels. An optimal candidate will violate AssociateHead(consonant) whenever it violates AssociateHead([+high], [ATR]), so this constraint will also be omitted for the time being, as it is the same issue.

Now this set of constraints will correctly derive [ɔuɛ]. First, violability of (26) rules out opacity of high vowels:

(27) *Wolof transparency: *A-Span forces violation of AssociateHead*

/√ɔ + ue/ → ɔuɛ	*A-Span	AssociateHead ([+high], [ATR])
a. (ɔ̲[u]ɛ) ~ (ɔ̲)(u̲e)	W $_{0\sim1}$	L $_{1\sim0}$

The losing candidate in (27a) has an opaque high vowel; this is blocked by the undominated *A-Span.

Second, violability of (26) rules out harmonic behavior by high vowels, when harmony would result in a prohibited feature value:

(28) *Wolof transparency: *[+high, –ATR] forces violation of AssociateHead*

/√ɔ + ue/ → ɔuɛ	*[+high, –ATR]	AssociateHead ([+high], [ATR])
a. (ɔ̲[u]ɛ) ~ (ɔ̲ʊɛ)	W $_{0\sim1}$	L $_{1\sim0}$

The losing candidate in (28a) has a harmonizing high vowel which takes on –ATR; this is blocked by the undominated *[+high, –ATR].

A complete ranking can be derived by noting that Wolof high vowels will never spread their value to the stem:

(29) *Wolof transparency: *[+high, –ATR] forces violation of AssociateHead*

/√ɔ + ue/ → ɔuɛ	FaithStem	AssociateHead ([+high], [ATR])
a. (ɔ̲[u]ɛ) ~ (ou̲ɛ)	W $_{0\sim1}$	L $_{1\sim0}$

Thus Wolof ATR harmony is predictable via the following ranking:

(30) *Wolof ATR harmony and disharmony*:
{*A-Span, FaithStem, *[+high,–ATR]} >>
{AssociateHead([+high],[ATR]), FaithHead(+ATR), FaithHead(–ATR), Head([–high],[+ATR]), Head([–high],[–ATR])}

The remaining AssociateHead constraints can be ranked following the observations made above; AssociateHead([–high,–low],[ATR]) and AssociateHead([+low]) will never be violated, whereas AssociateHead([+cons],[ATR]) will be violated whenever AssociateHead([+high],[ATR]) is. This issue will be addressed more explicitly in section 4.

This approach has a number of precedents. First of all, there is some phonetic basis for such an assertion. Gafos (1996) and Gafos and Benus (2003) report that transparent vowels are, in fact, articulated differently in harmonic environments than in isolation. That is, the [u] in [bɔkkulɛɛn] is acoustically somewhat different from [u] by itself. Gafos and Benus experimented with Hungarian, and not Wolof, but this is certainly a finding that is suggestive of some degree of participation by transparent vowels in harmonic contexts.

Furthermore, most theories of vowel harmony (including Span Theory, as presented up to this point) tacitly assume that harmony is a somehow unique process that operates only on vowels. Typologically, there may be less evidence to support such an assumption than would be expected. For instance, consider the case of emphasis spread in Palestinian Arabic, where emphatic (that is, –ATR) consonants spread their value to adjacent segments (example from McCarthy 1997):

(31) ḅạḷḷạṣ 'earthenware jar'

It seems entirely reasonable to analyze (31) as a single span, headed by the emphatic consonant [ṣ]. The suggestion put forth in this paper is that emphasis spread and more "conventional" ATR harmony are in fact different constraint rankings in a single typology of harmony predicted by Span Theory.

The remainder of this paper will consider the typological implications of this analysis.

3. Predictions: opacity in harmony

Section 2 has shown that transparency is derived from a ranking of *A-Span >> AssociateHead, if some constraint preventing harmony (generally markedness) also outranks AssociateHead. This set of constraints predicts another system, specifically that in which the markedness constraint and AssociateHead outrank *A-Span. Such a ranking will produce opaque vowels which not only fail to harmonize, but in fact initiate their own domain of harmony. This pattern is even more common than vowel transparency.

Akan (Dolphyne 1988), a Kwa language of Ghana, provides a clear example of vowel opacity. Akan has a nine-vowel system consisting of four alternating pairs of +ATR/–ATR vowels and one opaque –ATR vowel with no alternant:

(32) *Akan vowel system*

	front		back	
	+ –	–	+ –	
	i ɪ		u ʊ	high
	e ɛ		o ɔ	mid
		a		low

In general, co-occurrence of +ATR and –ATR vowels is highly marked; many words contain vowels from only one class, as in the following:

(33) a. wu-be-√tu 'you will dig it up'
2SG-FUT-dig
b. wʊ-bɛ-√tʊ 'you will throw'
2SG-FUT-throw
c. o-√di 'he eats'
3SG-eat
d. ɔ-√dɪ 'he is called'
3SG-be.called

Such a pattern looks much like that of Wolof harmony. However, the low vowel /a/ is always realized faithfully; furthermore, it prevents spreading of [+ATR]:

(34) a. bi**a**ra 'any'
b. ɔk**a**m**a**fo 'advocate'
c. o-√bis**a**-ɪ 'he asked'
3SG-ask-PAST

In example (34c), the low vowel /a/ prevents spreading of [+ATR] to the PAST suffix. In terms of Span Theory, /a/ initiates a –ATR span:

(35) (ob<u>i</u>)(s<u>a</u>ɪ)

Thus the output has two spans, and two domains of ATR values.

Formalization of the basic system in Akan can be accomplished in nearly the same way as non-transparent cases in Wolof; the only difference is that the disharmonic vowels in Wolof are high, whereas in Akan they are low. Thus different HEAD constraints are necessary[6]:

(36) HEAD([–low], [+ATR]): Non-low vowels head +ATR spans.
(37) HEAD([–low], [–ATR]): Non-low vowels head –ATR spans.

Other than this change, the non-disharmonic cases can be predicted with the same ranking that was used for Wolof:

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[6] Again, this is an approximation. In reality, there is a pair of HEAD constraints for every feature combination; however, there is no reason to distinguish between classes in Akan, since high and mid vowels behave in the same way with regards to ATR harmony.

(38) *"Non-disharmonic" Akan ATR harmony*:
{*A-SPAN, FAITHSTEM} >> {HEAD([–low],[+ATR]), HEAD([–low],[–ATR]), FAITHHEAD(+ATR), FAITHHEAD(–ATR)}

The real difference between the harmony systems of Akan and Wolof is the kind of disharmony. In both Akan and Wolof, disharmony is due to a specific prohibited feature combination: [+high, –ATR] for Wolof, and [+low, +ATR] for Akan. The formal difference is that Wolof disharmony requires disagreement with the head of a span – specifically, violation of an ASSOCIATEHEAD constraint. Disagreement with the head of an ATR span is never permitted in Akan.

The disharmonic low vowel will always initiate a new domain of the [–ATR] feature. Thus while there is presumably a featural co-occurrence constraint *[+low, +ATR], the grammar must also predict that /a/ will head a span. This is accomplished through the following constraint[7]:

(39) HEAD([+low], [–ATR]): Low vowels head –ATR spans.

Disharmony of low vowels requires the grammar of the language to rule out both transparent behavior, as represented by violation of the constraint ASSOCIATEHEAD([+low],[ATR]), and harmonizing behavior, as represented by satisfaction of *A-SPAN:

(40) *Akan ATR harmony: Violation of *A-SPAN permits opacity*

/ɔ-√bisa-i/ → obisaɪ	ASSOCIATEHEAD ([+low],[ATR])	HEAD([+low], [–ATR])	*[+low, –ATR]	*A-SPAN
a. (obi̲)(sa̲ɪ) ~ (obi̲s[a]i)	W $_{0\sim1}$	W $_{0\sim1}$	$_{0\sim0}$	L $_{1\sim0}$
b. (obi̲)(sa̲ɪ) ~ (obi̲sæi)	$_{0\sim0}$	W $_{0\sim1}$	W $_{0\sim1}$	L $_{1\sim0}$

The ranking ASSOCIATEHEAD([+low], [ATR]) >> *A-SPAN is a sufficient condition to prevent transparency of /a/, as shown by (40a). However, opacity itself must be derived from some constraint prohibiting [+low, +ATR] being ranked over *A-SPAN, as shown in (40b). Presumably this constraint can be *[+low, +ATR], but HEAD([+low], [–ATR]) is still needed to derive Akan vowel harmony. Although it will have no readily surface-apparent effects, it is formally necessary to produce the proper output representation (that in which the low vowel heads the disharmonic span) given an input such as /√bi-ta-i/:

[7] The opposing constraint, HEAD([+low], [+ATR]) is also posited to exist, but it is likely subject to a universal ranking of HEAD([+low], [-ATR]) >> HEAD([+low], [+ATR]), following the observations of Archangeli and Pulleyblank (1994).

(41) *Akan ATR harmony: Head([+low], [–ATR]) determines head*

/√bi-ta-i/ → bitaɪ	Head([+low], [–ATR])	Head([–low], [–ATR])
a. (bi̲)(ta̲ɪ) ~ (bi̲)(taɪ̲)	W $_{1\sim0}$	L $_{0\sim1}$

The general structure of this constraint system is somewhat analogous to systems such as Wolof; there, the ranking of *A-Span over the AssociateHead constraint prevents harmony, but for transparency to be apparent in surface forms, the grammar must have some markedness constraint ranked above AssociateHead.

Non-low vowels, in contrast, neither initiate their own spans nor disagree with heads; in other words, they are fully harmonizing. This is accomplished by allowing either AssociateHead(–low, [ATR]) or *A-Span (or both) to outrank all constraints which might motivate disharmony. For example, /ɔ+√di/ surfaces as [odi] since violation of FaithHead(–ATR) can be forced:

(42) *Akan ATR harmony: Violation of FaithHead(–ATR) causes harmony*

/ɔ+√di/ → odi	AssociateHead (–low, [ATR])	*A-Span	FaithHead (–ATR)
a. (odi̲) ~ (ɔ)(di̲)	W $_{0\sim1}$	W $_{0\sim1}$	L $_{1\sim0}$

The disharmonic nature of /a/ extends even to stems in Akan. This is no problem for the analysis; it simply must require stems to be faithful at the expense of harmony:

(43) *Akan ATR harmony: FaithStem forces violation of *A-Span*

/√bisa/ → bisa	FaithStem (ATR)	*A-Span
a. (bi̲)(sa̲) ~ (bɪsa̲)	W $_{0\sim1}$	L $_{1\sim0}$

Such a ranking predicts that all disharmonic roots will be permitted. This is not the case in Akan, although a language with such a system might exist. While this issue is not by any means unique to Span Theory, it can be easily accounted for in this framework. Specifically, FaithStem(ATR) can be divided into components for each value of the feature:

(44) *Akan ATR harmony: Dominant +ATR harmony in roots*

/√kɔko/ → koko	FaithStem (+ATR)	*A-Span	FaithStem (–ATR)
a. (kok*o*) ~ (kɔ̲)(ko̲)	$_{0\sim0}$	W $_{0\sim1}$	L $_{1\sim0}$
b. (kok*o*) ~ (kɔ̲kɔ)	W $_{0\sim1}$	$_{0\sim0}$	L $_{1\sim0}$

The FAITHSTEM(ATR) violation in (43) is really a violation of FAITHSTEM(+ATR). Thus the rankings entailed by (43) and (44) can be fused to produce at FAITHSTEM(+ATR) >> *A-SPAN >> FAITHSTEM(–ATR). The overall ranking necessary for Akan is the following[8]:

(45) *Akan ATR harmony*:
{HEAD([+low],[–ATR]),FAITHSTEM(+ATR),ASSOCIATEHEAD([±low],[ATR]), *[+low,+ATR]}>>
*A-SPAN >>
{FAITHSTEM(+ATR), HEAD([–low],[+ATR]), HEAD([–low],[–ATR]), FAITHHEAD(+ATR), FAITHHEAD(–ATR)}

Opacity in Span Theory, then, is really just a function of ranking the HEAD constraints high enough. The remaining properties of the disharmonic vowel /a/ in Akan are derived easily from differential faithfulness to values of [ATR].

4. Predictions: typology

On a theoretical level, it argues that opacity and transparency emerge from the relative positions of association and heading constraints – that is to say, in this theory such patterns are not *exceptions* to harmony, as they are treated in many approaches. Rather, harmony, opacity, and transparency are all direct results of the linguistic representation of feature manifestation as a process of association with headed spans.

Harmony will arise from the following generalized ranking:

(46) *Generalized harmony*
{*A-SPAN[F], ASSOCIATEHEAD([βG, γH, …], [F])} >> FAITHHEADSPAN[αF]

The essential element of such a ranking is that those constraints which motivate a specific value of a feature are ranked below those constraints which motivate extension of spans and association with spans. Opacity arises from the following:

(47) *Generalized opacity*
HEAD([βG, γH, …], [αF]) >> *A-SPAN[F]

This looks much like the ranking for harmony, except that the constraints motivating heading are ranked above *A-SPAN[F]. This means that initiating a new span is a less severe violation than disobeying markedness pressures towards headedness. Finally, transparency is produced by the following:

[8] As noted above, a number of slight variations on this ranking will also produce the Akan system; for instance, two of ASSOCIATEHEAD([±low],[ATR]), HEAD([+low],[–ATR]), and *[+low, +ATR] must outrank *A-SPAN, but there is more than one system which can produce this.

(48) *Generalized transparency*
{*A-SPAN[F], *CO-OCCURRENCE} >> ASSOCIATEHEAD([βG, γH, …], [F])

Here the essential element is that those constraints which motivate maximal spreading of features and those which motivate particular values both outrank the constraints on association with span heads. Thus the rigidity of span structure can be violated if doing so is necessary to prevent multiple spans or impossible feature combinations.

Different rankings of the constraints can also represent a language with a combination of transparent and opaque vowels. Examples of this sort are quite rare, though some highly decayed (diachronically) cases such as the Ewe vowel harmony system (Clements 1974, Duthie 1996) may fall into this category. On the other hand, transparent consonants combined with both opaque and harmonizing vowels are very common (Akan, for instance).

For the sake of easy illustration, suppose that it is possible to "conjoin" Akan and Wolof to produce a language with transparent high vowels and opaque low vowels:

(49) a. √be.te.ke b. √bɛ.tɛ.kɛ c. √be.**ta**.kɛ
d. √be.ti.ke e. √bɛ.**ti**.kɛ

Following (46) through (48), it is possible to "conjoin" the rankings necessary for harmony in Akan and Wolof. The ranking {ASSOCIATEHEAD([+low], [ATR]), HEAD([+low], [–ATR])} >> *A-SPAN captures opacity of low vowels. In turn, the ranking {*A-SPAN, *[+high,–ATR]} >> ASSOCIATEHEAD([+high], [ATR]) captures transparency of high vowels. There is no conflict between these rankings, so this system can be represented:

(50) *Transparency due to low ranking of *ASSOCIATEHEAD([+high], [ATR])*

/√bɛ+ti+ke/ → bɛtikɛ	*A-SPAN	*[+high,–ATR]	*ASSOCIATEHEAD ([+high], [ATR])
a. (b<u>ɛ</u>t[i]kɛ) ~ (b<u>ɛ</u>tɪkɛ)	$_{0\sim0}$	W $_{0\sim1}$	L $_{1\sim0}$
b. (b<u>ɛ</u>t[i]kɛ) ~ (b<u>ɛ</u>)(t<u>i</u>ke)	W $_{0\sim1}$	$_{0\sim0}$	L $_{1\sim0}$

(51) *Opacity due to low ranking of *A-SPAN*

/√be+ta+kɛ/ → betakɛ	ASSOCIATEHEAD ([+low], [ATR])	HEAD([+low], [–ATR])	*A-SPAN
a. (b<u>e</u>)(t<u>a</u>kɛ) ~ (b<u>e</u>t[a]ke)	W $_{0\sim1}$	W $_{0\sim1}$	L $_{1\sim0}$
b. (b<u>e</u>)(t<u>a</u>kɛ) ~ (b<u>e</u>tæke)	$_{0\sim0}$	W $_{0\sim1}$	L $_{1\sim0}$

Up to this point this analysis has been generally ignoring consonants. However it is simple to derive a pattern in which vowels and consonants both harmonize for ATR, similar to the pattern in Palestinian Arabic. This merely requires a ranking of *A-

SPAN(ATR) over the language's HEAD constraints and FAITHHEADSPAN([±ATR]). Each variety of ASSOCIATEHEAD must be present, but if nothing conflicts with it (i.e. if the language permits both +ATR and –ATR segments), then its ranking is indeterminate. Then given an input /√b̙e+bobi/, the grammar will spread [–ATR] over both vowels and consonants:

(52) **A-SPAN induces consonant emphasis*

/√b̙e+bobi/ → b̙εb̙ɔb̙ɪ	*A-SPAN	HEAD([segment], [±ATR])	FAITHHEADSPAN ([±ATR])
a. (b̙̱εb̙ɔb̙ɪ) ~ (b̙̱)(e̱)(ḇ)(o̱)(ḇ)(i̱)	W $_{0\sim5}$	L $_{5\sim0}$	L $_{5\sim0}$

(53) *ASSOCIATEHEAD causes harmonic bounding of transparent candidates*

/√b̙e+bobi/ → b̙εb̙ɔb̙ɪ	ASSOCIATEHEAD ([+cons], [ATR])
a. (b̙̱εb̙ɔb̙ɪ) ~ ([b]ε̱[b]ɔ[b]ɪ)	W $_{0\sim3}$

Note that this system also predicts the reverse case, which is somewhat unusual: vowel harmony inducing consonant emphasis.

On the other hand, a ranking banning RTR consonants such as {*A-SPAN, *[+cons, –ATR]} >> ASSOCIATEHEAD([+cons], [ATR]) will result in transparent consonants and harmonizing vowels. This is what occurs in most canonical vowel harmony systems:

(54) **[+cons, –ATR] forces violation of ASSOCIATEHEAD([+cons],[ATR])*

/√bε+bobi/ → bεbɔbɪ	*A-SPAN	*[+cons, –ATR]	ASSOCIATEHEAD ([+cons],[ATR])
a. ([b]ε̱[b]ɔ[b]ɪ) ~ (b̙ε̱b̙ɔb̙ɪ)	$_{0\sim0}$	W $_{0\sim3}$	L $_{3\sim0}$
b. ([b]ε̱[b]ɔ[b]ɪ) ~ (ḇ)(ε̱)(ḇ)(o̱)(ḇ)(i̱)	W $_{0\sim5}$	$_{0\sim0}$	L $_{3\sim0}$

Note that there are also a number of ways to derive systems with no visible harmony patterns. One example of this is a hypothetical language in which /ε/ is the only segment allowed to be –ATR. This is formally captured by a constraint MHYP. If *A-SPAN and MHYP dominate all ASSOCIATEHEAD constraints, the output will show no spreading at all:

(55) *No spreading: transparency of all segments*

/√bɛ+bo+bi/ → bɛbobi	*A-SPAN	MHYP	ASSOCIATEHEAD ([segment],[ATR])
a. ([b]ɛ̲[b][o][b][i]) ~ ([b]ɛ̲[b]ɔ[b]ɪ)	$_{0\sim0}$	W $_{0\sim2}$	L $_{5\sim3}$
b. ([b]ɛ̲[b][o][b][i]) ~ (b̲)(ɛ̲)(bo̲bi)	W $_{0\sim2}$	$_{0\sim0}$	L $_{5\sim0}$

This case, in which the majority of segments are transparent, is one instance in which no harmony surfaces. The other case in which such a pattern will be observed is the case in which all segments are opaque. This is formalized by ranking all faithfulness constraints above *A-SPAN, as in the following:

(56) *No spreading: opacity of all segments*

/√bɛ+bo+bi/ → bɛbobi	FAITHHEADSPAN (ATR)	*A-SPAN
a. (b̲)(ɛ̲)(b̲)(o̲)(b̲)(i̲) ~ (b̞ɛ̲b̞ɔb̞ɪ)	W $_{0\sim5}$	L $_{5\sim0}$

Thus the factorial typology of this extended Span Theory predicts that all systems of feature spreading can be captured by the same basic classes of constraints.

In summary, this account makes a fundamental claim about the nature of features and featural association: some features (ATR being one) spread via violable association with headed span structures. The Optimality Theory formalization of this approach allows for languages with both transparent and opaque segments.

5. Conclusion

The central claim of this paper has been that a revised form of Span Theory can produce a cohesive account of vowel harmony and disharmony. Specifically, vowel opacity and transparency both arise naturally from the rankings of those constraints on featural spreading. The distinction between opacity and transparency is captured by the relative ranking of the ASSOCIATEHEAD constraint with respect to those constraints motivating both harmony and specific feature values.

Qualitatively, this paper argues that vowel harmony and disharmony are driven by four main pressures: the pressure to be faithful, the pressure to form spans, the pressure to associate with spans, and the pressure to be less marked (via both heading and featural restrictions). Each component of this system is violable, and the relative rankings of the constraints determine whether a segment is opaque, harmonic, or transparent. Opacity is not an exception, but rather a stronger pressure towards a particular span type. Transparency is not an exception, but rather a weaker pressure towards association and a stronger pressure towards a particular value.

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