Tone Melodies in the Age of Surface Correspondence

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1 Introduction

The behavior of tone systems was a central motivation for Autosegmental Phonology (AP; Goldsmith 1976; Leben 1978), a theory couched in phonological representations and rules operating over representations. Because tone seems to do everything that segmental features can and more (Hyman 2012, it made sense to design a theory around tone and then to apply its apparatus to the tamer behavior of consonants and vowels. Since the introduction of Optimality Theory (Prince & Smolensky 1993), however, tone has been relegated to an increasingly peripheral role in theoretical development. New, surface correspondence-driven approaches to segmental effects of harmony and dissimilation (e.g., Agreement and by Correspondence, or ABC; e.g., Hansson 2001, Rose & Walker 2004, Bennett 2013) supplant the rules and representations once needed in AP to handle consonant and vowel harmony. So where does this leave tone?

In this paper, we utilize ABC to reexamine tone melody inventories, a landmark phenomenon in the development of AP. We argue that, under a correspondence approach, tone melody inventories emerge naturally from the phonological grammar, rooted in independently-motivated principles of similarity and proximity with proven effects in segmental phenomena. Our results illustrate that generalizations about tone melody distribution that originally drove the development of AP in fact provide unique arguments in support of a surface correspondence analysis. An ABC-driven approach arguably allows more fine-grained predictions in OT for the behavior of tone, and unites the analysis of tone and segmental patterns without the need for the the representations and rule-based mechanisms of AP.

2 Tone melodies

The association of autosegmental tone melodies to tone-bearing units is a canonical example of what AP was designed to do. Familiar to all students of tone are the the Obligatory Contour Principle in (1), and the universal tone-associations in (2) (Goldsmith 1976):

(1) Obligatory Contour Principle: no adjacent identical autosegments

(2) Universal Association Conventions
  a. Associate tones to tone-bearing units (TBUs) in a 1-1, L-R manner
  b. Spread the rightmost tone to any remaining toneless TBUs
  c. Dock any leftover tones to the rightmost TBU

The OCP and Universal Association Conventions team up to produce the famous Mende 5-way tone melody pattern (Williams 1971; Leben 1973, 1978) (also attested in Kukuya; Hyman 2007). As seen in Table 2, only 5 (OCP-conforming) melodies are posited in UR. Each noun is lexically associated with one of these five. The association of tones to TBU's is predictable from the number of TBUs in the noun:

Melody in UR	σ	$\sigma\sigma$	$\sigma\sigma\sigma$
L	L	L.L	L.L.L
H	H	H.H	H.H.H
L H	$\widehat{\text{LH}}$	L.H	L.H.H
H L	$\widehat{\text{HL}}$	H.L	H.L.L
L H L	$\text{L}\widehat{\text{HL}}$	L.$\widehat{\text{HL}}$	L.H.L

Table 1: Mende tone melodies, following e.g. Leben 1973

When the number of TBUs in the word exceeds the number of tones in the melody, Association Convention (2b) is responsible for the spreading of the rightmost tone, producing stretches of level tone at the end of the word. Whent he number of tones in the melody exceeds the number of TBUs, Association Convention (2c) takes over, producing contours. On this account, all contour tones will be final, and all stretches of level tone will include the final TBU. This latter generalization famously parallels the distribution of root consonants in Arabic verbs, under the name of Greenberg's Generalization, whose implementation in Autosegmental Theory by McCarthy (1979, 1981) was pivotal in the emergence of AP as the dominant analytical framework of the 1970's and 1980's.)

Crucially, on this view, a contour tone is a complex melody —a string of tones— associated with a single TBU.

3 Challenges for the AP melody account

The AP melody account of Mende, as sketched above, suffers from three problems, two well-known. The first problem is that Mende exhibits melodies beyond the 5 canonical ones posited by Williams and Leben, a problem pointed out by Dwyer 1978. The second, also pointed out by Dwyer (1978) (see also Conteh et al.) is that the alignment of melody tones to TBUs frequently violates the Universal Association Conventions. The third problem, which to our knowledge has not previously been discussed, is that melody complexity in Mende is correlated with word length to a degree greater than chance. We will discuss these three challenges in turn, before presenting our own alternative account of the distribution of lexical tone in Mende nouns.

The data that forms the basis for this discussion is list of 4,000 headwords taken from Innes's (1969) Mende dictionary, of which ca. 2,700 are nouns. This is the subset of words for which the AP melody analysis was said to hold, and we will largely limit ourselves to nouns here as well. ca. 2,500, or 92

3.1 How many tone melodies?

A search of the 2,700 nouns in the Mende lexicon reveals many melodies. Considering only distilled melodies that conform to the OCP, i.e. disregarding for now the alignment of tones to syllables and just focusing on the overall contours of the melody, Table 3.1 reveals the following:

Melody in UR	σ	$\sigma\sigma$	$\sigma\sigma\sigma$
L	25	251	25
H	53	531	101
LH	27	400	112
HL	31	243	127
LHL	9	276	204
HLH	0	6	22
LHLH	0	3	13
HLHL	0	11	12
LHLHL	0	1	10

Table 2: Mende tone melodies for nouns in dictionary

The important point to observe here is the numbers of nouns in the rows below the first five 'official' melodies. Although there are fewer nouns associated with HLH, LHLH, HLHL and LHLHL melodies, the numbers are not zero.

Certainly the AP account could be modified to include more than 5 underlying melodies, increasing its descriptive adequacy. It is interesting to note, though, the commitment at the time to capturing those melodies which appear *most common*; this anticipates the goal of modern-day maximum entropy grammars, namely predicting not only which structures are possible but their relative probabilities. The binary method used in the AP analysis of listing or not listing a melody is ultimately too crude a method of predicting distributions to be useful, but the laudable goal of predicting distributions is something we will pick up in our own analysis, to be presented in section XXXX.

3.2 Tone alignment

A topic of discussion in the early days of the AP account of Mende was the number of exceptional nouns in which the alignment of melody tones to TBUs violates the Universal Association Conventions. For example, consider the four nouns in (3):

(3) Examples of exceptional tone alignment in Mende

a.	HL	ngíla	'dog'
b.	HL	ngɔ́ngɔ̂	'tooth'
c.	LH	ndàvúlá	'sling'
d.	LH	lèlèmá	'praying mantis'

The two disyllabic nouns in (3a,b) both have HL melodies, yet the tones align differently. To account for this discrepancy, Leben (1978) proposed prelinking H to the second syllable of *ngɔ́ngɔ̂*, the noun not conforming to the Universal Association

Conventions. The two trisyllabic nouns in (3c,d) both have LH melodies, but only (3c) conforms to the Universal Association Conventions. However, the alignment pattern of (3c) was though to be the more common pattern for longer words with LH melody. To account for this, Leben (1878) proposed to modify Association Convention (2a) so that in a LH melody, the H would associate to the final syllable, rather than obeying left-to-right, 1-1 association. This modification rendered (3d) the well-behaved form and (3c) the exceptional form; Leben account for forms like (3c) through prelinking of the H to the second syllable.

The issue of unpredictable tone alignment goes way beyond just these examples, however (e.g., Dwyer 1978, Conteh et al. 1983). Table 3.2 shows the large number of nouns whose surface patterns do not conform to the predictions of the Association Conventions, even with Leben's (1978) modification. Forms in bold conform to the modified conventions; plain forms violate them.

σs	Melody	n	σs	Melody	n	σs	Melody	n
1	**H**	53	3	**L.H.L**	142	3, cont.	H.L.LH	1
	HL	31		**H.H.H**	101		HL.H.HL	1
	LH	27		**L.L.H**	63		HL.H.L	1
	L	25		H.H.L	58		**L.H.LH**	1
	LHL	5		L.H.H	40		L.HL.HL	1
	LHHL	4		**H.L.L**	38		LH.LH.L	1
2	**H.H**	531		L.L.HL	31			
	L.H	380		H.H.HL	25			
	L.L	251		**L.L.L**	25			
	H.L	212		**H.L.H**	21			
	L.HL	204		LH.L.L	17			
	LH.L	64		LH.L.H	12			
	H.HL	17		LH.L.HL	8			
	HL.L	14		**H.L.HL**	7			
	LH.H	13		LH.H.H	6			
	HL.HL	11		HL.L.L	5			
	LH.HL	8		L.H.HL	4			
	L.LH	7		LH.H.HL	4			
	H.LH	4		LH.H.L	4			
	HL.LH	2		H.LH.L	3			
	LH.LH	2		L.L.LH	3			
	LH.LHHL	1		L.HL.L	2			
	LHHL.H	1		H.HL.L	1			

Table 3: Mende tone melodies for 1-3 syllable nouns in dictionary

While successful at handling forms just like those in (3), the AP account is weakened by the number of unpredictable forms (11%) that require lexical prelinking of tone. 2-syllable words, the success rate of Leben's modified Association Conventions is only 92%, but for 3-syllable words where there is more work for the Association Conventions to do, it is only 60%.

3.3 Tone Melody Complexity

A key insight of the AP account, and a hallmark of the predictions of the Association Conventions is the independence of tone melody from characteristics of the noun with which it is lexically associated. Leben (1978:186) writes that “By regarding the tone pattern as phonologically separate from the segments in these words, we capture the fact that a given pattern can occur regardless of how many syllables a word has." [Leben 1978:186]. Inspection of the Mende lexicon suggests that this prediction is not borne out for Mende. Rather, the longer the word, the more likely a complex melody.

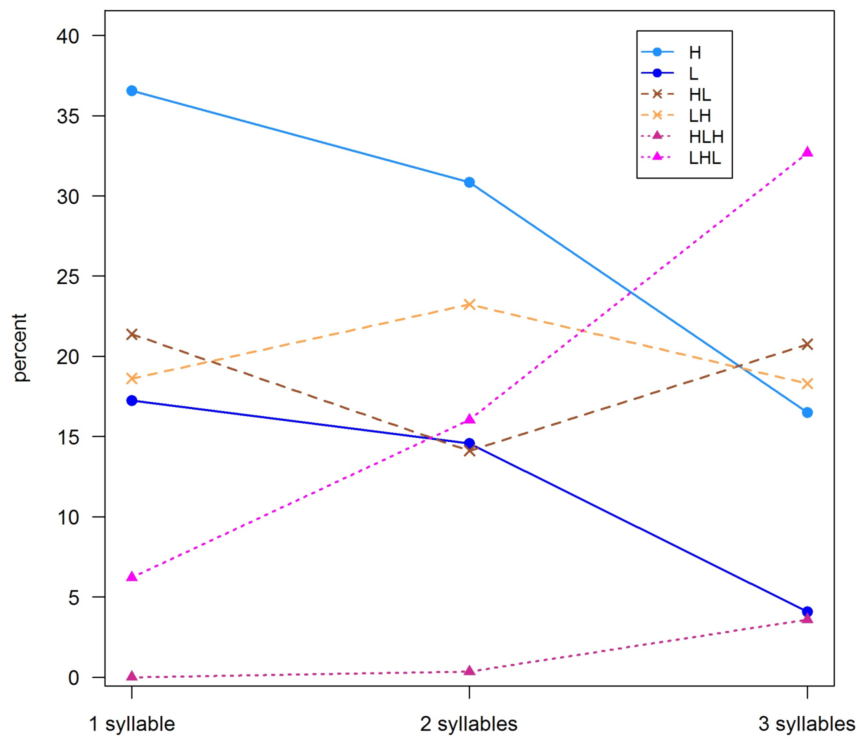

Figure 1: Tone melody complexity by word length

The inevitable conclusion from this finding is that the distribution of tone on surface syllables in Mende is driven by principles that either supplement or, ideally, fully supplant the original principles of AP.

4 A fresh look at tone

The goal of this study is to take a fresh look at tone, to transcend the familiar analytical space of AP, with its floating tones and association conventions, and develop a new set of principles to govern the distribution of tone in Mende nouns. Specifically, we strive in this study to characterize the distribution of tone using the same kinds of tools that have proven so successful in the analysis of long-distance (and local) segmental phenomena, namely correspondence constraints based on proximity and similarity. We conclude that the resulting model is better suited than AP to predicting the observed surface tone patterns in the Mende lexicon.

The framework that we use for this analysis is twofold, a combination of Agreement by Correspondence Theory (ABC) (Hansson 2001, Rose & Walker 2004, Bennett 2013) and Q-theory, a theory of subsegmental structure developed in Shih & Inkelas (2013).

Agreement by Correspondence (ABC), originally developed for long distance consonant agreement but since extended to vowel harmony and other local harmonies, is a theory of syntagmatic interactions. The key claim of ABC is that syntagmatic units which are both sufficiently similar and sufficiently close to one another will correspond, and thus interact. Interaction occurs when correspondence between elements which are similar yet not identical is unstable; interaction either improves identity (assimilation) or undoes correspondence (via dissimilation, deletion, or other repairs). Assimilation and dissimilation are thus repairs for unstable correspondence.

Q theory addresses the question of what units the correspondence constraints of ABC can refer to. The standard in the ABC literature is for correspondence constraints to refer to segments. The theory has also been applied to strings of segments, inasmuch as it has been invoked to handle reduplication (Yu 2005, Inkelas 2008; see also Zuraw 2000 for a conceptually similar approach under a different name). ABC has its formal roots in Correspondence theory; see e.g. McCarthy & Prince 1994. But assimilation and dissimilation effects involving complex segments frequently demand a finer-grained level of representation for constraints to operate on. This is where Q-theory steps in. Building off the earlier Aperture Theory of Steriade (1993), Q theory proposed that every segment 'Q' (every vowel, every consonant) is decomposed into a small number of sequenced, featurally uniform subsegments ('q'). This is illustrated in (4) for vowels and consonants:

(4) Q-theory: representations

Q $(q^1\ q^2\ q^3)$	
V$(v^1\ v^2\ v^3)$	(a vowel)
C$(c^1\ c^2\ c^3)$	(a consonant)

In Q theory, each q subsegment is featurally uniform. Complex segments are Q's whose q's do not all agree featurally, as illustrated in (5a-b). A TBU with contour 'tone' is one whose internal q's are not tonally uniform (5c):

(5) Q-theory: contour segments

a.	V(e a i)	the Romanian triphthong *eai* (e.g., Dindelegan 2013)
b.	C(n d z)	the prenasalized affricate ^{n}dz
c.	V(à á à)	a LHL contour on the vowel [a], e.g. Mende *mbâ* 'companion'
	V(à á á)	a LH contour
	V(á á á)	an all-H vowel

As example (5) indicates, the TBU in ABC+Q theory is, narrowly defined, the subsegment. Broadly speaking, the TBU is whatever string of q's a given correspondence constraint refers to. Below, we will motivate several constraints that constraint tonal correspondene at the Q level, as well as constraints that constrain tone correspondence at the q level of representation.

5 The ABC+Q analysis of Mende noun tone

Below we develop ABC+Q constraints that, embedded in a MaxEnt model, predict the inventory and relative frequency of attested tone melodies of the 2,700 Mende nouns in the database. The constraints take the form of similarity- and proximity-based correspondence and identity requirements. Each is motivated by an empirical aspect of the data. The analysis makes no reference to autosegmental representations, to tone association rules, to the OCP, or to tone contours or melodies as units of grammar.

5.1 Level vs. contour: the need for syllable-internal q correspondence

Our first observation over the 2,700 Mende nouns in the lexicon is that syllables with contour tone are relatively infrequent. Tabl (4) shows the relative frequence of contour vs. level-tone syllables in Mende nouns. Of the syllables with contours, 76% are in final position.

Syllables with contours	587	10.75%
Syllables with level tone	4,874	89.25%

Table 4: Contour vs. level-tone syllables, all 1-3 syllable Mende nouns

To model this asymmetry in the distribution of contours, we introduce the concept of correspondence and tonal identity between q subsegments within the same syllable. The correspondence constraints in (6) follow the general pattern of any correspondence constraint in ABC. The first, very general constraint compels correspondence between any consecutive pair of q subsegments. The second constraint compels correspondence between any consecutive pair of *tautosyllabic* q subsegments. The third constraint, which plays a major role in Mende, compels correspondence between any consecutive pair of *tautosyllabic* q subsegments in a weak, or nonfinal, syllable. Shown here are only the CORR constraints. These constraints are, of course, accompanied by Ident-qq[tone] constraints (not shown), compelling tonal identity among corresponding q's.

(6) qq Correspondence

CORR-qq	q subsegments correspond
CORR-q::q	strictly adjacent q subsegments correspond
CORR-$[q::q]_\sigma$	tautosyllabic adjacent subsegments correspond
CORR-$[q_w::q_w]_\sigma$	tautosyllabic adjacent subsegments in nonfinal syllables correspond

Tableau (7) compares two possible alignments of a LHL tone sequence on a disyllabic word. As seen, the CORR-$[q_w::q_w]_\sigma$ constraint favors the alignment in which the first syllable has level tone and the contour occurs on the final syllable. CORR constraints penalize any change of tone across consecutive q's The penalty is higher if the tone change takes place within a (nonfinal) syllable

(7) A preference for contours to be final

		CORR-$[q_w::q_w]_\sigma$	CORR-$[q::q]_\sigma$	CORR-qq
a	L.HL (= $l_x l_x.h_y l_z$)		1	2
b.	LH.L (= $l_x h_y.l_z l_z$)	W	1	2

5.2 A preference for tones to change at syllable boundaries

In polysyllabic nouns with a complex (non-level) tone melody, it is more common for tone to change across than within syllables. The table in (5) shows that it is far more common to have a tone transition (e.g. ...H.L..., ...L.H... etc.) at a syllable boundary than for tone to remain the same (e.g. ...LH.H..., ...L.L... etc.)

tone changes at syllable boundaries	1,532	79.0%
tone agreements across syllable boundaries	408	21.0%

Table 5: Tones on either side of a syllable boundary, all 1-3 syllable Mende nouns

To account for this observed tendency, we invoke a Limiter constraint of the sort proposed in Bennett (2013) to handle dissimilation in ABC. Limiter constraints penalize correspondence across specified boundaries between elements of specified similarity. Dissimilation can undo the similarity and remove the compulsion to correspond, satisfying the limiter constraint:

(8) Limiter constraint on trans-boundary correspondence

qq-EDGE-σ Assess a violation for each pair of corresponding q subsegments separated by a syllable boundary

The effect of combining qq-EDGE-σ with the CORR constraints in (6) is to derive another generalization we have already observed, namely the correlation between the number of tonal transitions in a word (the complexity of its 'tone melody') and the number of TBUs in that word. As shown in 5.2, where two tableaus compare different tone alignments on candidates of equal length, the grammar prefers those candidates with tonal transitions at syllable boundaries and level tones within nonfinal syllables. This preference is reflected in the observed frequencies with which the alignments being compared here are actually found in the Mende lexicon. The alignment preferred by the grammar is the most frequent:

	$\sigma\ \sigma$	*freq*	qq-EDGE-σ	CORR-$[q_w::q_w]_\sigma$	CORR-qq
☞ a.	L.H (= $l_x l_x.h_y h_y$)	**380**			1
b.	L.L.(= $l_x l_{x,y}.l_{y,z} l_z$)	251	W1		L
	$\sigma\ \sigma\ \sigma$	*freq*	qq-EDGE-σ	CORR-$[q_w::q_w]_\sigma$	CORR-qq
☞ a.	L.H.L (= $l_x l_x.h_y h_y.l_z l_z$)	**142**			2
b.	L.L.L (= $l_x l_{x,y}.l_{y,z} l_z.h_a h_a$)	63	W1		L1
c.	L.H.H (= $l_x l_x.h_y h_{y,z}.h_{z,a} h_a$)	40	W1		L1
d.	L.L.L (= $l_x l_{x,y}.l_{y,z} l_{z,a}.l_{a,b} h_b$)	25	W2		L
e.	$\widehat{\text{LH}}$.L.H ((= $l_x h_y.l_z l_z.h_a h_a$)	12		W1	3

Table 6: A preference for contours to be final

5.3 A bias toward H

In nouns in the Mende lexicon, syllables with H tone (53%) slightly outnumber those with L (47%). Among words with level tone, all-H predominates (69%) over all-L (31%). This 'H bias' can be modeled by a markedness constraint favoring H tone; among the possibilities, we favor HAVE-H, since the strongest effect of the H bias is seen in level-tone words.

(9) HAVE-H: A word should have at least one H-toned subsegment

5.4 A bias against HLH

Given the bias in favor of H, it is perhaps surprising that Mende also exhibits a bias against HLH sequences. This was already indicated by the decision in the AP era to leave HLH off of the list of top-5 melodies that Mende nouns are said to exhibit. We know from a search of the dictionary that HLH does in fact occur in Mende, but it is not as common as LHL. Indeed, LHL sequences outnumber HLH sequences for words of all lengths. The disparity decreases with word length:

	σ	$\sigma\ \sigma$s	$\sigma\ \sigma\ \sigma$
LHL	11	382	156
HLH	0	27	49

Table 7: LHL vs. HLH melodies, 1-3 syllable nouns in Mende

The bias against HLH sequences appears stronger the closer together the two H's are. This lends itself very naturally to modeling in the ABC framework. We propose the following two constraints. The first (10) requires a pair of consecutive H-toned subsegments to correspond (regardless of distance); the second (11), following the format developed by Bennett 2013, requires corresponding H-toned subsegments to be adjacent.

(10) CORR-q[H]q[H]: H-toned q subsegments must correspond

(11) q[H]q[H]-qADJ: Corresponding H-toned q subsegments must be adjacent

Requring corresponding H's to be adjacent is the constraint that deives tone plateauing in languages that have it. Tone plateauing is the phenomenon whereby a stretch of L tone between two H's raises to H, creating a 'plateau' of level-H tone. In Mende, the constraint simply causes the grammar to favor HLH sequences over LHL sequences, as illustrated below. (The relatively low-ranked HAVE-H is suppressed in this tableau for reasons of space.)

	$\sigma\ \sigma\ \sigma$	*freq*	qq-EDGE σ	q[H]q[H]-qADJ	CORR -q[H]q[H]
☞ a	H.L.H (= $h_xh_x.l_yl_y.h_xh_x$)	(21)	W2	W1	
b.	H.L.H (= $h_xh_x.l_yl_y.h_zh_z$)	21			W1
c.	H.H.H (= $h_xh_{x,y}.h_{y,z}h_{z,a}.h_{a,b}h_b$)	101	W2		
d.	L.H.L (= $l_xl_x.h_yh_y.l_zl_z$)	142			

Table 8: The LHL bias in action

6 ABC+Q and AP-style analyses compared

Having discussed the insights behind the original AP analysis of Mende, the generalizations emerging from a closer inspection of the Mende data, and the corresponding constraints that comprise an ABC+Q analysis of the data, we are now in a position to compare the two approaches side by side. We will do this by means of a maximum entropy model that examines which type of model is better able to predict the existence and relative frequency of attested surface tone patterns in Mende nouns.

On the left in Table XX are the constraints we have developed thus far for the ABC+Q analysis of Mende. On the right are constraints that model the original AP analysis. ALIGN-R(H.H, L.L) corresponds to Association Convention (**??**b), namely spreading of the rightmost tone. ALIGN-R($\widehat{\text{HL}}$, $\widehat{\text{LH}}$) corresponds to Association Convention (2c), namely docking of leftover tones to form contours. (It is equivalent to Zoll's (2003) COINCIDE-CONTOUR constraint, accomplishing the same goal of limiting contour tones to the final syllable.) The OCP and *HLH (accounting for the absence of HLH in lexical tone melodies) complete the original AP analysis. Because the original AP analysis was all about tone alignment, not about predicting melody frequency, we have augmented it here with two constraints: *CONTOUR and HAVE-H, which have counterparts in the ABC+Q constraint set. These constraints capture the bias toward level tones and toward H, which contribute to the accuracy of melody frequency rankings.

The analyses have comparable numbers of constraints, and even overlap in one constraint (HAVE-H). But they differ in their key insights, as reflected in the constraints that they do not share. The AP account places the burden of explanation

ABC+Q	AP	Notes
CORR-qq	ALIGN-R(H.H, L.L)	“spreading", (2b)
CORR-$[q_w{::}q_w]_\sigma$	ALIGN-R($\widehat{HL}$, $\widehat{LH}$)	“docking", (??c); see Zoll 2003
qq-EDGE σ	OCP	limits underlying melodies
CORR-q[H]q[H]	*HLH	rules out HLH, LHLH, HLHL, etc. melodies
q[H]q[H]-qADJ	*CONTOUR	*update added in this paper*
HAVE-H	HAVE-H	*update added in this paper*

Table 9: ABC+Q and AP analyses, side by side

on a fixed set of melodies that are aligned in predictable ways. The ABC+Q account places the burden of explanation on correspondence. H-subsegments should correspond (and be adjacent); subsegments should not correspond across syllable boundaries; subsegments should correspond within nonfinal syllables.

In comparing these two models, with their different foundational insights, we use a Maximum Entropy Harmonic Grammar (MaxEnt) model (Goldwater & Johnson 2003; Wilson 2006), with constraint weights fitted using maximum likelihood estimation in the MaxEnt Grammar Tool (Hayes et al. 2009). The goal of this model is not to generate the optimal output for a given lexical input. Rather, it is to assess the relative harmony of different possible tone patterns for a word of given length. MaxEnt ranks probabilities (i.e. comparative grammaticality) of outcome candidates in variable data, based on the following formula:

For our purposes, the input is a fixed number of syllables; the output is a ranked list of possible tone patterns, with the expectation that the top-ranked pattern is the most frequent.

$$Pr(x) = \frac{exp(-\mathcal{H}(x))}{\sum_{y\in\Omega} exp(-\mathcal{H}(y))}$$

where *x* is the candidate surface form in question, $\mathcal{H}$ is the harmony score of a candidate (w·C), and *y* ranges over all of the candidate surface forms in the candidate set Ω.

In 2 we see the predicted frequencies assigned to surface melodies for trisyllabic words by the ABC+Q and AP models, compared to the observed frequencies of these melodies on nouns in the Mende database.

As seen in 2, ABC+Q predicts the same top-ranking surface tone patterns for trisyllabic words that we see observed in the lexicon. In trisyllable words, the most common observed surface tone patterns are L.H.L. H.H.H, L.L.H, H.H.L, L.H.H, and H.L.L. The most frequent by far is L.H.L. The ABC+Q approach predicts this predominance of L.H.L. This tone pattern changes tone at every syllable boundary, has no contours, has one H, and avoids trough. In contrast, the AP analysis fails to assign additional probability to L.H.L; it predicts incorrectly that in trisyllabic words, L.H.L will have probability equal to that of H.H.H, L.H.H and H.L.L. While ABC+Q correctly predicts that the top six patterns are the most common, the AP account ranks L.L.H and H.H.L too low, and ranks L.L.L too high. This is because

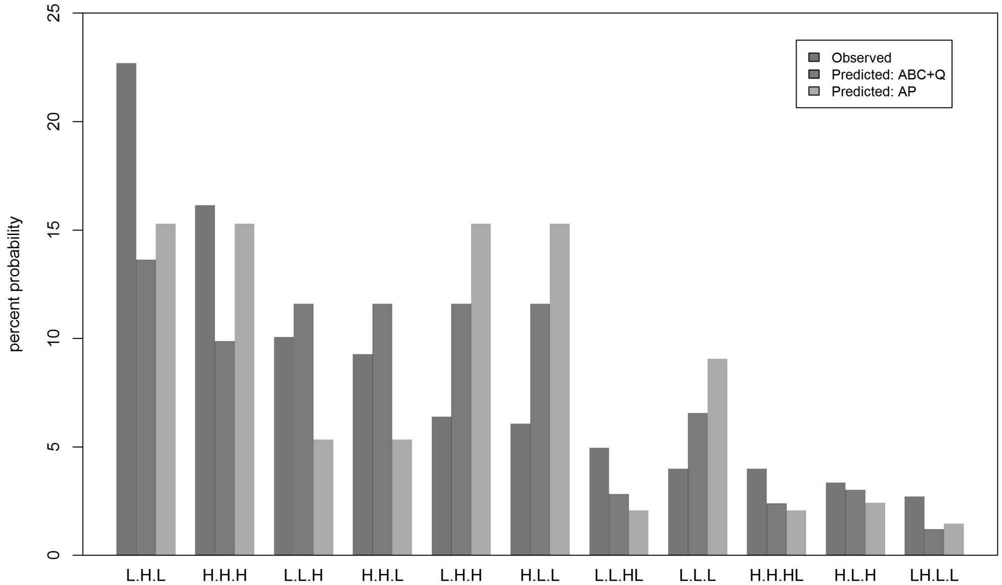

Figure 2: ABC+Q and AP models, vs. observed data: trisyllabic words

the AP account assigns all (licensed) melodies the same probability and focuses its attention on aligning level tone stretches and contour tones with the right edge, rather than on what is happening at internal syllable boundaries.

7 Where both models could stand to improve

While the ABC+Q model does better than the AP model at predicting the frequency distribution of tone patterns in trisyllabic words (as well as shorter words, shown below), both models show subpar performance in two areas, creating an interesting pointer towards future refinement and research. The first is alignment. As can be seen in Figure 2, the observed frequency of L.L.H (10.06%) and H.H.L (9.27%) patterns is greater than that of L.H.H (6.39%), H.L.L. (6.07%). The ABC+Q account assigns all four patterns the same probabilty, failing to capture the differential, while the AP account predicts the *opposite* differential. The empirical observation is that two-tone patterns with a late transition from one tone to the next seem to be favored (Cahill 2007). This is the opposite of what the Universal Association conventions predict; the 1-1, L-R association convention (**??**a) predicts early, not late, transitions. It was to address this failing in the AP vision that Leben (1978) proposed Mende-specific revisions to tone mapping, though only for the LH melody, and that Zoll (2003) proposed to do away with 1-1 L-R mapping and use *Clash (for H.H) and *Lapse (for L.L) to regulate the distribution of level tone stretches. To capture the asymmetry between L.L.H   H.H.L and L.H.H   H.L.L, the ideal model of Mende tone would need to add a constraint, perhaps perceptually motivated, favoring tonal transitions which are later rather than earlier in the word. This would require a mechanism beyond what has been proposed so far in this paper, as currently ‘transition’ is not a representational entity that constraints can refer to.

A second area in which both models fall short is the overattestion of the level H surface pattern. In 2, the ABC+Q account incorrectly predicts level-H to be less frequent than the tone-tone patterns (L.L.H, H.H.L, L.H.H, H.L.L), when in fact it is more frequent than these. The AP account incorrectly predicts that level-H will be as frequent as L.H.L, L.H.H, and H.L.L. The effect is even more noticeable in monosyllabic words, depicted in 3. Here, while both ABC+Q and AP accounts correctly assign the highest predicted frequency to level-H, both models overpredict the frequency of level-L, i.e. insufficiently account for H bias.

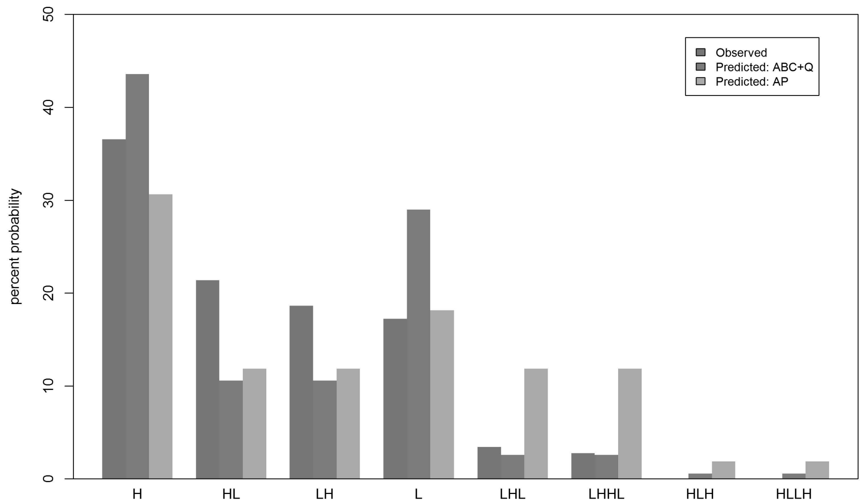

Figure 3: ABC+Q and AP models, vs. observed data: monosyllabic words

It is interesting to note, as depicted in Figure 4, that the H bias weakens as words get longer. This decline is captured better in ABC+Q than in AP, which in its original incarnation had complete independence between melody and word length. ABC+Q predicts a decline of level-H words because of qq-EDGE-σ, which favors tone transitions at syllable boundaries. In AP, level-H should be just as likely as any other of the five existing melodies, regardless of word length, though we did enhance the AP account with HAVE-H and *CONTOUR, which (like their counterparts in ABC+Q) contribute to the predicted predominance of level-H on monosylalbic word specifically.

While both models give words with level H a boost over words which are level-L, neither is giving all-H words a sufficient boost across words of all lengths. There are several ways to imagine doing this. One is to model a multiplicative effect of HAVE-H at each domain (word, syllable, segment). Another is to invoke a constraint favoring H on every TBU, not just on every word, which could supplement or supplant our existing HAVE-H. A third avenue of investigation lies in the func-

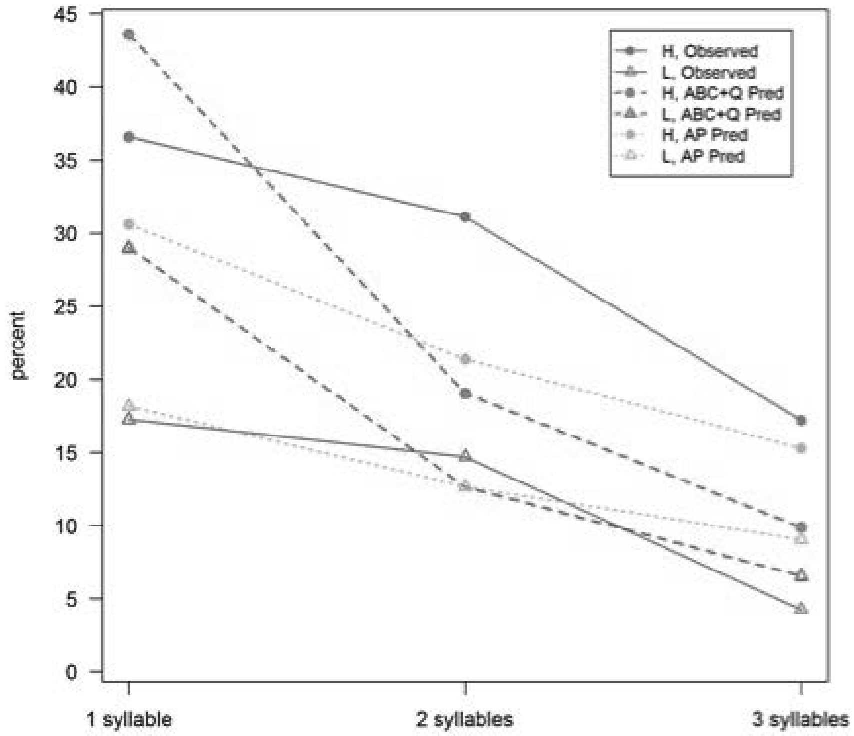

Figure 4: H tone overattestation as function of word length

tional load that tone melodies are performing. We have not paid attention in this work to morphophonological effects, e.g. the use of certain tone melodies in morphological derivation. But in analyzing the headwords from the dictionary we are able to look at the distribution of tone melodies across different parts of speech. Interestingly, the greatest area of discrepancy across parts of speech lies precisely with level-H and level-L patterns. Figure **??** shows that the level-L melody is highly characteristic, not of nouns, but of adverbs and function words. It might thus be that the apparent H bias in nouns is due to the disfavoring of level-L in nouns, in asmuch as level-L is indexed to other parts of speech.

7.1 Correlation of tone melody complexity and word length

We noted earlier in the paper the empirical generalization that tone melody complexity tends to increase with greater word length. We return, at the end of the paper, to a demonstration that the ABC+Q account predicts this correlation better than the AP account. As seen in Figure **??**, the ABC+Q account outperforms the AP account in predicting this correlation, which is not surprising, given the key insights underlying each model:

What is perhaps more interesting is to ask whether, in the light of all of the findings of this paper, it is meaningful to characterize a language as a 'tone melody' language in the way that Mende has been characterized. Certainly it is the case that

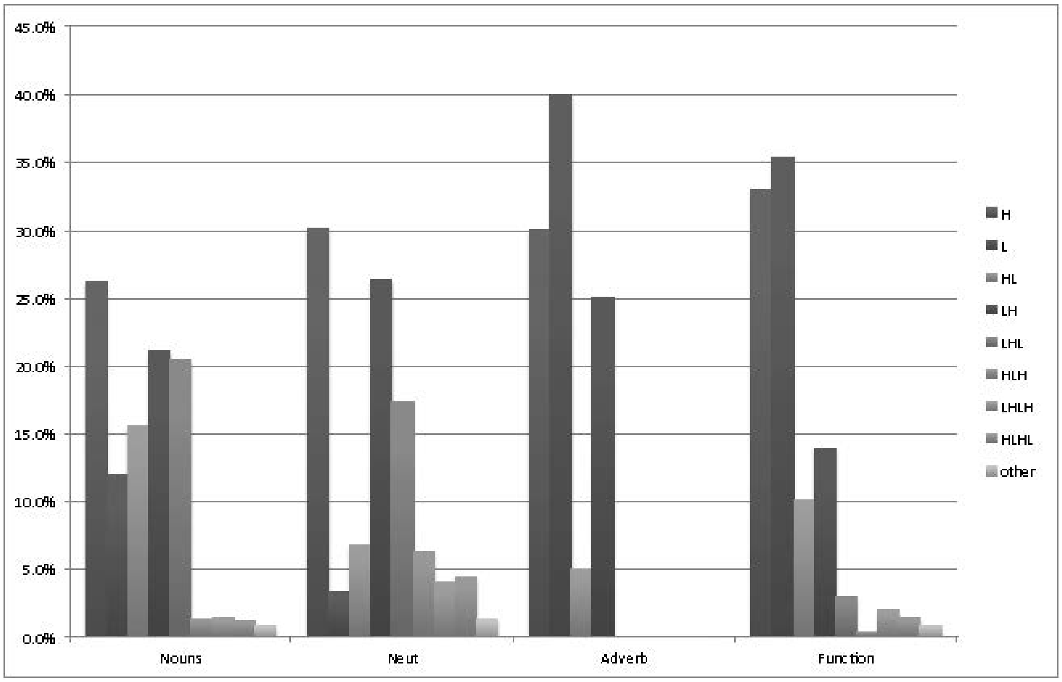

Figure 5: Relative frequency of Mende tone melodies by part of speech

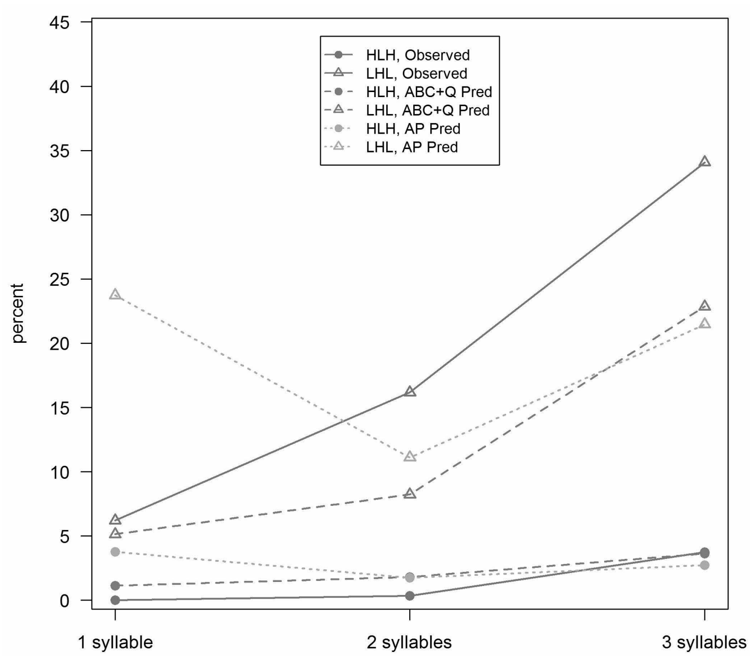

Figure 6: Predicted vs. observed frequency of complex melodies, by word length, in Mende

there are 5 or 6 very frequently occurring ‘melodies’ in Mende nouns. But is this due to a special organization of the system, as early AP accounts proposed, or is it a conspiracy of many very general constraints on tone that are shared by other language as well? To gain a glimpse into how this question might be answered, we looked briefly at a small (ca. 3,000) word lexicon of Hausa, a language which is well known to use melodies in its morphotonology but which has never been claimed to show evidence of tone melodies in its monomorphemic nouns. Our finding, depicted in Figure 7, is that Hausa looks very similar to Mende in the respect that surface tone ‘melody’ complexity correlates with word length. (Hausa does not allow rising ($\widehat{\text{LH}}$) tone within a syllable, which accounts for the lack of $\widehat{\text{LH}}$ and L$\widehat{\text{H}}$L melodies on monosyllabic nouns.)

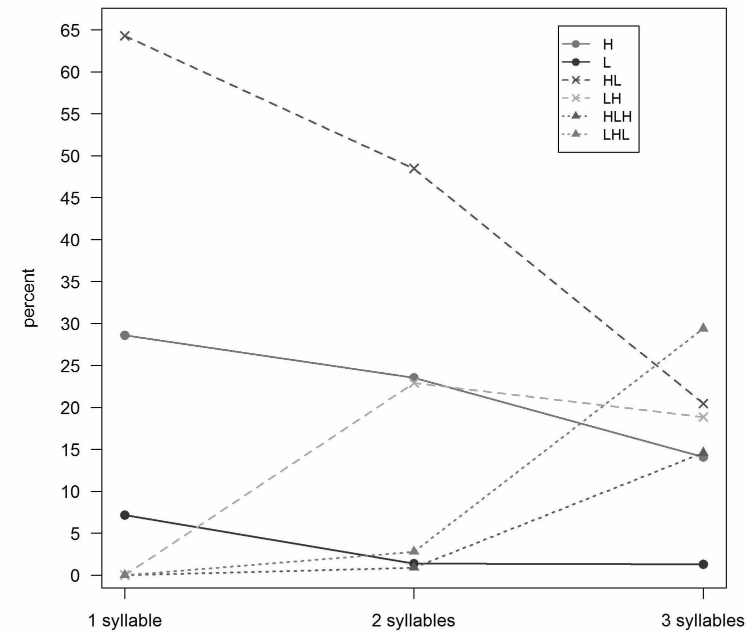

Figure 7: Predicted vs. observed frequency of complex melodies, by word length, in Hausa

8 Conclusion

The goal of this paper was to examine surface tone melody patterns in a classic “melody tone” language, namely Mende, in order to see whether this apparent exotic and tone-specific phenomenon might be capturable without recourse to the representational machinery of AP. The alternative proposal we considered is the surface-oriented, correspondence-driven optimization of ABC, enhanced with the phonetically grounded subsegmental representations of Q theory. Our findings are that the ingredients of an ABC+Q analysis, namely correspondence constraints based on similarity and proximity, produces surprisingly accurate predictions about the lexical distribution of surface tone sequences. This distribution can be achieved with the need to a priori limit the melodies available to words. On the ABC+Q analysis, the melody inventory is emergent from the grammar. ABC+Q does not need to make overt reference to melodic ‘units’ (like H, or L, or LH).

This analysis has several theoretical advantages. First is that it solves a problem that has lurked behind the scenes in the AP era, namely the need to refer to contour tones as units even though they are not constituents in AP representation. Constraints which license contour tones in final (or other position) are at odds with the position that contour tones in AP are sequences of elements, not unit on their own. This is a known problem for the analysis of languages in which contour tones assimilation or dissimilate; see e.g. Yip xxxx, Inkelas & Shih (in progress).

Second, the ABC+Q analysis of tone carries the distinct advantage of analyzing tone using the same types of representations and constraints that are used for segmental phonology. Just like vowel and consonant harmony, tone patterning is driving by pressures of correspondence at thresholds of similarity and proximity. Porting the analysis of tone into surface correspondence theory, and discarding representations that are unique to tone, allows tone to take its proper place as a central phenomenon in phonological theory, and for theory to properly embrace an important observation made by Hyman (2011:214):

> “Tone is like segmental phonology in every way—only more so!"