MORAIC ANCHORING OF f_0 IN WASHO

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ABSTRACT

Recent research shows that the minima and maxima of pitch accent and tonal contours are often aligned with segmental anchors. The present study examines the f_0 alignment properties in Washo, an endangered language of California and Nevada. Washo is particularly interesting because, unlike other languages which have been studied thus far, it not only has a vowel length distinction, but also has what is known as 'stress-sensitive quantity alternations' [10]: long stressed vowels are followed by a short consonant (V:C), while short stressed vowels are followed by a geminate (VC:) This paper reports the results of an acoustic experiment demonstrating that the anchoring of f_0 landmarks in Washo crucially make references to anchors at the moraic rather than the segmental level. It is found that H anchors consistently with the second mora of the stressed vowel. L, meanwhile, cannot be anchored to the onset of the stressed vowel without reference to the sonority of segments preceding the tonic vowel.

Keywords: Tune-text alignment, f_0 anchoring, endangered languages, native American languages.

1. INTRODUCTION

In the decades following Bruce's study of Swedish word accents [2] and Pierrehumbert's subsequent study of English intonation [6], there has been much interest in the temporal coordination of f_0 and phonetic segments. Specifically, it has been suggested that it is not the *contour* of a pitch excursion or tone contour that matters, but rather certain target destinations; as Arvaniti et al. put it [1], the important thing is to be in "the right place at the right time." Caspers & van Heuven [3] demonstrated that the f_0 minima (L) in Dutch anchors to the onset of the stressed syllable. This conclusion was affirmed and augmented by Ladd et al. [5], who were also able to consistently locate the f_0 maxima (H) at the tonic vowel offset. Other studies of Indo-European languages have indicated similar conclusions. Arvaniti et al. [1] showed that Greek aligns L with the onset of the accented syllable, and H with the post-tonic syllable, and Prieto et al. [7] gave evidence for Mexican Spanish.

Several studies have shown that this pitch anchoring is independent of the effect of speech rate and segmental composition. Ladd et al. [5], for example, studied the former and found that in British English, as the speech rate increases, the targets become closer and the pitch excursion becomes steeper, validating the anchoring hypothesis. Xu [8], meanwhile, looked at tonal contours in Mandarin in both open syllables and syllables ending in a nasal (the only possible final consonant in the language). He showed that the anchoring is unaffected by syllable composition or speech rate.

Washo is a highly endangered Hokan language spoken near Lake Tahoe in Nevada and California in the western United States. The data from Washo will be interesting in this debate because a language with a vowel-length distinction *and* quantity sensitivity has not yet been studied. The varied realization of the tonic vowel and the post-tonic consonant may provide compelling evidence for the true nature of pitch anchoring. §2 consists of an introduction to Washo phonetics and phonology. §3 describes the methodology for this experiment, and §4 gives the results. §5 will be dedicated to an interpretation and analysis of the data, including their wider theoretical implications. The conclusion appears in §6.

2. WASHO PHONOLOGY

The segmental inventory of Washo is given in Figure 1. The vowel length distinction is phonological, but only in stressed vowels. Consonants may be geminated as a result of quantity alternation (see below & following page).

Figure 1 Washo phonemic inventory

a. vowels

	front	**mid**	**back**
high	i, i:	~~ɨ~~, ~~ɨ:~~	u, u:
medium	e, e:		o, o:
low		a, a:	

b. consonants

	lab.	alv.	post-alv.	vel.	gl.
stop, -voice	p	t		k	ʔ
stop, +voice	b	d	dz	g	
stop, ejective	p’	t’	ts’	k’	
fricative		s	ʃ		h
nasal, -voice	m̥			ŋ̊	
nasal, +voice	m	n		ŋ	
approx., -voice	ʍ	ɬ	j̊		
approx., +voice	w	l	j		

Stress generally lies on the penultimate syllable of the root (e.g., [dáŋːal] ‘house’; [deʃíːnaji] ‘ant.’) There also exist a small number of roots with ultimate stress (e.g., [ʃuʔwéːk] ‘clam’), as well as several suffixes which are inherently stressed (i.e. the negation marker *–éːs*, as in [jek’ilgéːsi] ‘it’s not sharp’).

In a recent study [10], it was found that long vowels are approximately twice the duration of short ones. When the stressed vowel is underlyingly short, the bimoraicity of the stressed syllable is achieved through post-tonic consonant gemination ([dáʃːaŋ] ‘blood’; [gajálːiʔ] ‘stand up!’). Underlyingly long vowels are already bimoraic, and thus do not require post-tonic consonant gemination: ([wáːlaʃ] ‘bread’; [káːŋi] ‘it’s roaring’).

This distinction, known as ‘quantity alternation’, provides a new and interesting testing ground for the theory of segmental anchoring. If segments are indeed the associative basis for pitch alignment, then it will be instructive to see how this alignment differs between long and short vowels in Washo, which give rise to differently realized stressed vowels.

3. THE EXPERIMENT

3.1 Methodology

This research is based on measurements of eighty tokens of two Washo speakers, taken from recordings of elicitations of word lists and short phrases. The informants, a man (SJ) and a woman (RD), are native speakers of Washo living near Lake Tahoe, and were recorded by the second author in 2004 and 2005. The recordings were made in a quiet room with a Marantz PMD670 solid-state recorder and a headset microphone set at a sampling rate of 44kHz.

The words selected met two main criteria. Since the study dealt with suprasegmental phenomena, tokens had to be minimally disyllabic; forty-nine of the tokens are disyllabic and twenty-eight are trisyllabic, while three have four syllables. Second, only words with a post-tonic resonant were selected, in order to ensure a continuous f_0 contour across the tonic and post-tonic syllables. The tokens were distributed approximately evenly between speakers (41% SJ ~ 59% RD) and between long and short stressed vowels (54% short ~ 46% long).

3.2 Measurements

Several other points and times were measured and calculated. L and H are the low and high points, respectively, of the f_0 contour. TMX is the time between the onset of the tonic vowel and H. MAXOFF is the time between H and the onset of the post-tonic consonant.

All measurements were made using PRAAT, and were determined according to the following procedures:

-*stops* were measured from the cessation of energy of the preceding segment until the burst of the onset of the following segment.
-*sibilants* were measured according to the presence of random frication noise.
-*glides* were measured from the midpoint of the transition from the preceding vowel to the midpoint of the transition into the following vowel.
-*nasals* and *approximants* were measured according to the spectral changes at onset and release.

The number of syllables, the length (short or long) of the tonic vowel, the speaker, and the quality of the pre- and post-tonic consonants were also noted. Consonants were classed into obstruents, nasals, approximants and glides. If there was a series of pre-tonic sonorants, as in [dimláːya] ‘my wife’, or if there was only one sonorant and a vowel preceding it, as in [demémːew] ‘ribs’, the entire pre-stress sonorous phase of sonorants and vowels was included in order to accurately locate L, as discussed in §4.2.

4. RESULTS

4.1 H.

A one-way ANOVA showed a significant effect of vowel length on H alignment ($F(1,78) = 10.46$, $p < 0.01$). When vowel is short, the mean measurement for MAXOFF is positive (6.2 ms), while when the vowel is long, the mean measurement is negative (-35.9 ms). What this means is that when a vowel is long, the f_0 peak precedes the post-tonic consonant, but that when the vowel is short, the peak comes later, usually in the post-tonic consonant. Viewed in terms of anchoring, this result makes it clear that the offset of the tonic vowel cannot be the anchoring point for the pitch peak, because it aligns quite differently with long and short vowels. Other factors were not statistically significant. To find out where H *is* anchored, then, the ratio of alignment of H over the combined duration of the VC sequence was calculated.

In short vowels, H occurs 54.45% of the way into the VC sequence, while in long vowels it comes 53.94% of the way through. The difference between these two numbers is not significant. Thus regardless of whether the vowel is long or short, H will always align with the midpoint of the VC sequence. Taken together, the results for the calculations of MAXOFF and TMX raise serious questions as to the validity of the segmental anchoring hypothesis for Washo, questions which shall be addressed in §5.

4.2 L

On average, L is realized 26 msec. before the onset of the tonic vowel. No significant effect of vowel length on the L anchoring is found. In order to ascertain more precisely the anchoring property of L, tokens with a pretonic sonorant (N = 32) were examined separately from those that begin with an obstruent (N = 48). A one-way ANOVA revealed an effect of pretonic consonant sonorancy on L anchoring ($F(1,78) = 134.2$, $p < 0.01$). When the pretonic consonant is an obstruent, L obtains at 22 msec. after the onset of the tonic vowel; when the pretonic consonant is a sonorant, L is realized 98 msec. prior to the onset of the tonic vowel. The significance of this result is, however, confounded by the fact that the majority of tokens with pretonic obstruents is disyllabic (73%), while the numbers of disyllabic syllables relative to the polysyllabic syllables in the pretonic sonorant token set are roughly equal. Thus the difference observed in L alignment relative to the sonorancy of the onset of the tonic syllable might reflect a difference in the absolute length of the token itself. A highly significant correlation between the temporal anchoring of L relative to the onset of the tonic vowel and word length was indeed observed ($r = -0.3$, $p < 0.01$). However, further correlation analyses revealed that a significant correlation was only apparent within the set of pretonic sonorant tokens ($r = -0.4$, $p = 0.023$), not within the set of pretonic obstruent tokens. This result suggests that that the sonorancy of the pretonic segment remains a significant factor. A linear regression analysis showed that the combined duration of the pretonic sonorous segments (i.e. sonorant onset of the tonic syllable, and, if present, the onset, nucleus and coda of the pretonic syllable) and the quality of the onset of the tonic syllable (i.e. obstruents, nasals, glides, or liquids) account for more than 75% of the variance of temporal anchoring of L ($R^2 = 0.76$, $F(2, 77) = 120.42$, $p < 0.01$).

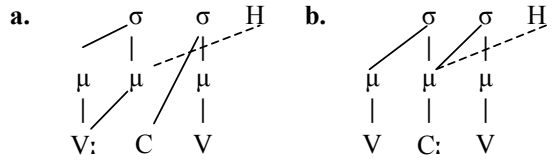
5. IMPLICATIONS

In §4.1 it was seen that on short vowels, H falls slightly after the tonic vowel offset. For long vowels, on the other hand, H is just before the tonic vowel onset. The most important implication of this incongruity is that short and long vowels in Washo do *not* behave exactly similarly with respect to f_0 anchoring. This significant difference in alignment proves that the segmental anchoring hypothesis reviewed in §1.1 does not account for the data presented here. Under segmental anchoring, one would expect that the phonological length of a vowel is would play no role in f_0 anchoring, but that is exactly what is found here.
What happens instead is that H consistently falls approximately half-way into the stressed VC sequence. This cannot be analyzed segmentally because this half-way point does not correspond systematically with the onset of the post-tonic consonant. Rather, it can only be understood with reference to the VC sequence. This sequence is interesting in itself because it falls across a syllable boundary. That is, the two segments involved do not make up any coherent part of the segmental string, such as the nucleus or the coda of a syllable. The only way to cogently analyze this sequence is with regard to moraic units. As seen in §2.2, Washo requires stressed vowels to be heavy, and that this requirement is met in two ways. Long

vowels, of course, are inherently bimoraic. Short vowels, on the other hand, are monomoraic and must add another mora when they are stressed. Yu [9] makes it clear that this is done through post-tonic consonant gemination, as demonstrated above in (7-9). Therefore, the common factor between V:C and VC: sequences in Washo, which the segmental theory of anchoring fails to account for, is that they both allow the stressed vowel to meet its bimoraicity requirement.

When one views the VC sequence as a meaningful unit comprising two moras, the anchoring of f_0 becomes clear. With short vowels, i.e. VC: sequences (see Figure 1b), the following consonant is ambisyllabic, functioning both as a coda of the stressed syllable (thereby adding an additional mora) and as the onset of the post-tonic syllable. With a long vowel (see Figure 1a), meanwhile, there already are two moras, so the following consonant is only the onset of the post-tonic syllable.

Figure 1. Moraic anchoring of H in V:C and VC: sequences



Crucially, in Figure 1a, the vowel already meets the bimoraicity requirement, and the consonant adds no weight to the stressed syllable.

In §4.2 it was shown that the alignment of L is largely determined by the duration of the sonorous pre-tonic sequence, and particularly by whether the pre-tonic consonant is a sonorant or an obstruent. Despite a potential confound in the number of syllables a word contains, therefore, the evidence is convincing that in Washo, the alignment of L can only be ascertained with reference to the quality of (at least) the pre-tonic consonant. Like the findings for H, this is problematic for the segmental anchoring hypothesis, which does not take segmental quality into consideration. Rather, it calls for a theory which allows for the effect not only of the segmental structure of words, but also of different properties of the segments themselves.

6. CONCLUSION

The data from Washo confirms the basic hypothesis of pitch anchoring, but it also provides important evidence contradicting some of the tenets outlined above. First and most importantly, the pitch contour in Washo is fixed with *moraic*, not segmental, landmarks. As will be seen, this accounts for the uniformity of the H location between stressed syllables of the forms V:C and VC:. Second, with regard to L, it is clear that the syllabic composition of the pitch domain is indeed relevant. L cannot be located at the onset of the stressed syllable without reference to the sonority of the pre-stress sequence. Since no other language with Washo's vowel quantity alternation has been studied in the context of pitch alignment, and since the sonority sensitivity exhibited by L has not yet been described, we believe that the data presented here constitutes an important advancement in this aspect of phonetic and phonological theory.

7. REFERENCES

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