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Journal of Phonetics

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The phonetics of quantity alternation in Washo

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Received 16 February 2006; received in revised form 8 December 2006; accepted 30 October 2007

Abstract

Stress-sensitive quantity alternation is commonplace in the Uralic languages and many of the Germanic languages in and around the Scandinavia region, but few reports have detailed similar types of alternation in Native American languages. This study offers a quantitative analysis of the complementary length alternation between tonic vowels and post-tonic consonants in two generations of speakers of Washo, a severely moribund Hokan language spoken by approximately 13 elderly speakers near the California–Nevada border southeast of Lake Tahoe. The complementary alternation of vowel and consonant length is argued to be motivated by a previously unnoticed requirement in the language to keep the stressed syllable heavy. This paper reports the results of an acoustic study verifying the phonetic reality of this alternation by comparing the speech of two generations of speakers of Washo based on archival audio recordings made in the 1950s and recent fieldwork materials. The results show that the quantity alternation is much more pervasive in the language than it was first described in the 1960s. It is shown that the current generation of Washo speakers retains subtle phonetic alternations, despite the fact they mostly grew up bilingual, if not English-dominant. Their command of Washo phonetics and phonology does not seem to have undergone severe attrition. However, their realization of post-tonic long consonants was not as long in relative duration as the earlier generation. These results show the value of supplementing transcription with direct measurement, even with small numbers of speakers.

0. The phonetics of quantity alternation in Washo

Stress-sensitive quantity alternation—the co-variation of vocalic and post-vocalic consonantal length in syllables bearing stress—is commonplace in the Uralic languages (McRobbie-Utasi, 1999) and various Indo-European languages (Elert, 1964; Eliasson, 1985; Kiparsky, to appear; Kristoffersen, 2000; Leyden, 2002; Pind, 1999; Rice, 2003). For example, in Standard Italian, stressed syllables must be heavy (i.e., (C)Vː or (C)VC). Long vowels are never followed by a long consonant, however; a stressed long vowel is always followed by a short consonant while a stressed short vowel is followed by a long consonant (contrast [ˈfaːto] *fato* 'fate' vs. [ˈfatːo] *fatto* 'done'; Borrelli, 2000, p. 7). Few reports, let alone quantitative phonetic studies, have detailed similar types of alternation in the indigenous languages of North America, however (cf. Harms, 1966; Sapir, 1930; Woodbury, 1985). Syllable weight has also provided fertile grounds for research on the phonetics–phonology interface. Many studies on syllable-timing and syllable weight have demonstrated a convergence between phonological representations and phonetic facts (Broselow, Chen, & Huffman, 1997;

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doi:10.1016/j.wocn.2007.10.004

Please cite this article as: Yu, A. C. L. The phonetics of quantity alternation in Washo. *Journal of Phonetics* (2008), doi:10.1016/j.wocn.2007.10.004

Duanmu, 1994; Gordon, 1999, 2004; Hubbard, 1995). This article provides evidence from the perspective of an endangered Native American language, Washo. Previous phonological studies have proposed that syllables bearing stress in Washo must be phonologically heavy (i.e., (C)Vː or (C)VC). This paper shows the phonetic correlates of this phonological claim. The experimental evidence also reveals important generalizations that are completely absent in previous discussions of Washo phonetics and phonology. The results have implications for the description of the phoneme inventory, phonotactics, rule system and morphological structure of Washo.

Some scholars have suggested that a bilingual speaker of a threatened language in a language-contact situation will make fewer phonological distinctions in his or her use of the language than a fully competent (dominant or monolingual) speaker of the same language would (e.g., Andersen, 1982). With a few notable exceptions (e.g., McDonough & Austin-Garrison, 1994), however, there have been little quantitative phonetic studies testing the validity of this claim. The present study contributes to this discussion by examining the speech of Washo speakers from two time periods for potential cross-generational phonetic and phonological changes that might have taken place in the language.

1. Quantity alternation in Washo

Washo is a severely moribund language spoken by approximately 13 elderly speakers in an area around Lake Tahoe, California and Nevada. The name, Washo, also spelled Washoe, is an Anglicized version of the ethnonym, [ˈwaːʃiw]. The language is generally assumed to be part of the Hokan stock (Dixon & Kroeber, 1919; Harrington, 1917; Sapir, 1917, 1921), although some consider it a linguistic isolate (Campbell & Mithun, 1979). The phonemic inventory of Washo consonants is shown in Table 1. In syllable-final positions, the three-way laryngeal contrast neutralizes toward voicelessness.

The phonemic inventory of Washo vowels is given in Table 2 (Jacobsen, 1964, 1996). While the glides, /w/ and /j/, are in complementary distribution with the short high vowels *i* and *u*, there are no alternations that

Table 1
The consonants of Washo (Jacobsen's orthographic equivalence is given in / /)

	Bilabial	Alveolar	Post-alveolar	Velar	Glottal
Stop					
Voiceless	p	t		k	ʔ
Voiced	b	d	dz/z/	g	
Ejective	p'	t'	ts'/c'/	k'	
Fricative					h
Voiceless		s	ʃ/š/		
Nasal					
Voiceless	m̥/M/			ŋ̊/Ŋ/	
Voiced	m	n		ŋ	
Approximant					
Voiceless	ʍ/W/	ɬ/L/	j̊/Y/		
Voiced	w	l	j/y/		

Table 2
Vowels of Washo

	Front	Central	Back
High	i, iː	ɨ, ɨː	u, uː
Mid	e, eː		o, oː
Low		a, aː	

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support analyzing glides as underlying high vowels. Moreover, given that there are no voiceless vowels in Washo, glides are also better analyzed as consonantal for reason of symmetry in the voiced and voiceless sonorant series. Long vowels are found only in stressed syllables; short vowels can occur in any syllable. Stress is assigned to stems and is generally on the penultimate syllable, although a small subset of stems has final stress (e.g., [mu'daːl] *mudáːl* 'winnowing basket'; [ʃuʔ'weːk] š*uʔwéːk* 'clam'). When stress is final, the tonic vowel is invariable long.

According to Jacobsen's description, Washo has a restricted system of stress-governed quantity alternation. Post-tonic /s, ʃ, m, n, ŋ, j, l, w/ are lengthened intervocalically. No such lengthening is found elsewhere; while stress may fall on the stem-final syllable, as mentioned above, the tonic vowel is always long while the post-tonic consonant short. Thus, as illustrated in (1), when the tonic vowel is long, the following fricative, nasal, or glide, is short (1)a; when the tonic vowel is short, however, the post-tonic consonant is long (1)b. (Examples in the leftmost column are given in Jacobsen's phonemic transcription. Their corresponding IPA transcriptions are indicated in brackets.)

(1) a. **Singletons after a long stressed vowel (V:C)**

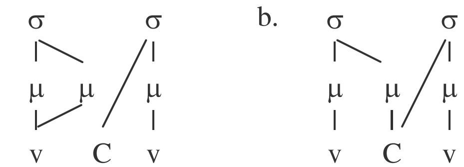
yáː**s**aʔ	['jaː**s**aʔ]	'again'
wáː**š**iw	['waː**ʃ**iw]	'Washo'
báː**m**uš	['baː**m**uʃ]	'muskrat'
ʔáː**n**i	['ʔaː**n**i]	'red ant'
k'áːŋi	['k'aːŋi]	'it's roaring'
wáː**l**aš	['waː**l**aʃ]	'bread'
p'áː**w**a	['p'aː**w**a]	'in the valley'
dimláː**y**aʔ	[dim'laː**j**aʔ]	'my wife'

b. **Geminates after a short stressed vowel (VC:)**

yá**s**aŋi	['ja**s**ːaŋi]	'it's hot'
dá**š**aŋ	['da**ʃ**ːaŋ]	'blood'
dá**m**uʔ	['da**m**ːuʔ]	'skirt'
tá**n**iw	['ta**n**ːiw]	'Miwok'
káŋa	['kaŋːa]	'cave'
šá**l**aʔ	['ʃa**l**ːaʔ]	'pitch'
dá**w**al	['da**w**ːal]	'buckberry'
ʔá**y**ɨs	['ʔajːɨs]	'antelope'

Recent studies have shown that this quantity alternation reflects a deeper phonological fact about Washo (Yu, 2005, to appear)—syllables bearing stress in Washo must be phonologically heavy (i.e., bimoraic). Supporting evidence comes from the distribution of the plural reduplicant and the behavior of floating moras in the language. Phonologically, the VːC sequence would be assigned a structure such as (2)a while the VCː sequence is assigned the structure in (2)b.

(2) a. b.



Several peculiarities of Washo obscure this generalization regarding the interaction of vowel and consonant length in relation to stress. First, this pattern of complementary length, i.e., either the stressed vowel or the post-tonic consonant is long, is uncommon among the languages of North America, although Southern Paiute (Uto-Aztecan), a neighboring language of Washo, is reported to have post-tonic gemination after voiceless vowels that bear stress (Harms, 1966; Sapir, 1930). The restrictiveness of the classes of segments that participate in lengthening is also unexpected since the geminating segments do not seem to form any transparent natural class. Jacobsen also notes that short stressed vowels before an intervocalic voiced stop are lengthened (3). However, no comparable lengthening of short vowels before plain voiceless stops and ejectives is reported. To be sure, Jacobsen found no lengthening of ejectives and plain stops after short tonic vowels either.

(3)	**lé**ːduŋ 'like me'	*l*-First person, -***í***- Pronoun stem, -*duŋ 'like'*
	ʔíːdaʔ 'he said …'	*ʔ*- Third Person, ***íd*** 'to say', -*aʔ* Aorist
	w**í**ːdiw 'these (pl.)'	*w**i***- Near Demonstrative Stem, -*di* Demonstrative Formative, -*w* Personal Plural

Previous studies on quantity alternation generally found such length alternation applying to all segmental classes in the appropriate contexts. The restricted distribution of complementary length in Washo thus seems unique from a cross-linguistic perspective. The co-variation of vocalic and consonantal length also lends itself to the interpretation that a principle of isochrony that holds across syllables bearing stress is at work in Washo. The acoustic study reported below is designed to determine the quantitative nature of quantity alternation in Washo, including the behavior of ejectives and plain stops in post-tonic contexts.

2. Experiment

2.1. Materials

The present study is based on two sets of audio recordings. The first set of materials is extracted from a subset of 35 reels of recordings deposited by Professor William Jacobsen Jr. at the Berkeley Language Center Language Archive. These are field recordings of fourteen Washo speakers made in the 1950s which include texts, word lists, grammatical notes, and songs. No information concerning the setting of the audio recordings is available. With the permission of Professor Jacobsen, the field tapes were digitized by the Berkeley Language Center at the request of the present author. The recordings are of reasonable quality and provide enough words recorded in one setting that comparison made on this basis might be considered representative of the variety of Washo spoken at the time (circa 1950s–1960s).

The second set of recordings is based on fieldwork conducted by the present author in Dresslerville, Nevada and Woodfords, California between 2004 and 2005. Three speakers were recorded, one male and two females, at or around the age of 70, with no speech impediment. These speakers are grand-relatives of the speakers interviewed by Professor Jacobsen. The recordings were made in a quiet room using a Marantz PMD670 solid-state recorder and a head-mounted microphone at a sampling rate of 44 kHz. Recordings include texts, word lists, and grammatical notes.

The present study examines the speech of four speakers, two from Jacobsen's recordings, and two from the present author's own fieldwork. The two speakers from the 1950s were Roy James (RJ) and Bertha Holbrook (BH). No biographical information is known about these speakers other than the fact that James was a resident at Woodfords, California while Holbrook was of Dresslerville, Nevada. They were among the main linguistic consultants Professor Jacobsen worked with at the time. The two current speakers of Washo featured in this study are Steven James (SJ) of Dresslerville, Nevada, and Ramona Dick (RD) of Woodfords, California.

A total of 631 tokens are collected for this study with the following break-down: 108 tokens from BH, 213 tokens from RJ, 188 from RD and 122 from SJ. The basic criteria in the selection of words to be included in the study were that the word must: (i) be minimally disyllabic where stress is not final; (ii) contain a stressed vowel that is not followed by a heterorganic consonant sequence; and (iii) have a post-tonic consonant that is either a nasal, an approximant, a sibilant, a plain stop, or an ejective.

2.2. Measurement

The duration of the post-tonic intervocalic consonants and their preceding stressed vowels are measured. All measurements were made with Praat (Boersma & Weenink, 1996), using the following segmentation criteria:

- *Oral stops*: The interval between the end and the reemergence of formant energy. This interval is often accompanied by the cessation of voicing at closure in voiceless stops (i.e., plain and ejectives). In the event of voicing during stop closure, the relative amplitude of F2 energy is used to finding oral closure onset and offset. This measure of oral stop duration thus includes the interval from consonantal release to onset of voicing. In the case of ejectives, the offset of the stop occurs at the glottal release.

- *Sibilants*: The interval between the onset and offset of frication noise.
- *Nasal stops and lateral*: The interval between abrupt spectral changes at closure onset and the release.
- *Glides*: Segmentation of glides is notoriously difficult (Liu & Xu, 2003; Xu & Liu, 2002). The duration of a glide is taken here to be the interval between the midpoint of transition from the vowel preceding the glide and the midpoint of transitions from the glide to the following vowel.

2.3. Results

2.3.1. Correlating tonic vowel and the post-tonic consonant duration

The scatter plots in Fig. 1 illustrate the relationship between the tonic vowels and the post-tonic consonants measured in this experiment. First, it can be observed that there is generally a more distinct separation (along the *x*-axis) between the long vs. short vowel tokens among speakers of the previous generation (BH and RJ). Some degree of overlap in post-tonic consonant duration is apparent in all speakers, although the current speakers (RD and SJ) reflect a less distinct separation between the long and short consonants. The scatter plots also show a clear separation of two clusters of data points, one containing the vowels and consonants in the VːC type (the filled circles), the other containing segments from the VCː type (the unfilled triangles). This separation suggests that the co-variation of tonic vowel and post-tonic consonant durations might be the results of categorical shifts. The results of a series of simple linear regression analysis are consistent with this interpretation. While the product-moment correlations in Table 3 show significant correlations between stressed vowel and post-tonic consonant durations for some speakers (BH, RJ, & RD), the results of the linear regression analysis show that tonic vowel duration is a poor predictor of post-tonic consonant duration. Even for RJ, the only speaker that shows vowel duration as a significant regressor of consonant duration in both VC sequence types, vowel duration nonetheless explains less than 20% of the post-tonic consonant duration data.

2.3.2. Factors influencing the duration relationship between tonic vowel and post-tonic consonant

The low r^2 values in Table 3 suggest that there is a large amount of variation within each set of data that is not accounted for by the tonic vowel duration alone. To examine the effect of other factors that might influence the variation in the duration of the tonic vowel and the post-tonic consonant, a subset of the data was subjected to further statistical analysis. The basic criteria in the selection of words for the second part of this study were that the word must contain a stressed /a/ or /e/ regardless of vowel length and the post-tonic consonant must be a nasal, an approximant, a sibilant, an ejective, a plain stop, or a voiced stop. A total of 515 tokens is included in the second part of the study (184 contain a stressed /e(ː)/; 331 contain a stressed /a(ː)/). A summary of tonic vowel and post-tonic consonant durations is given in Fig. 2.

The mean duration of VːC sequences is on average about 10% longer than that of the VCː type. These results suggest that the representational difference in (2) between VːC and VCː sequences is generally reflected in the phonetic realization. It should be noted that, while the duration difference is statistically significant for most speakers, this does not appear to be the case for RD's tokens. This lack of a significant difference might be related to the reduction of post-tonic consonant gemination in RD's speech (see discussion of consonant/vowel ratio below; Tables 4 and 7).

The quantity contrast in vowel length is examined next. A summary of the long-short vowel ratio of each subject is shown in Table 5. On average, long vowels are about 90% longer than the short vowels. A one-way ANOVA reveals this difference to be highly significant ($F(1.513) = 798.31$, $p < 0.001$). Vowel length is thus phonetically distinct in Washo, but there is some variation between speakers. For example, while long vowels are more than twice as long as the short vowels for BH, long vowels are only about 50% longer than the short vowel for RD. In order to determine which phonetic properties are good predictors of tonic vowel duration, a step-wise linear multiple regression analysis was carried out. The results of the regression analyses are shown in Table 8. Vowel quantity, subject identity, and consonant type were significant predictor variables ($p < 0.001$) for vowel duration ($r^2 = 0.67$).

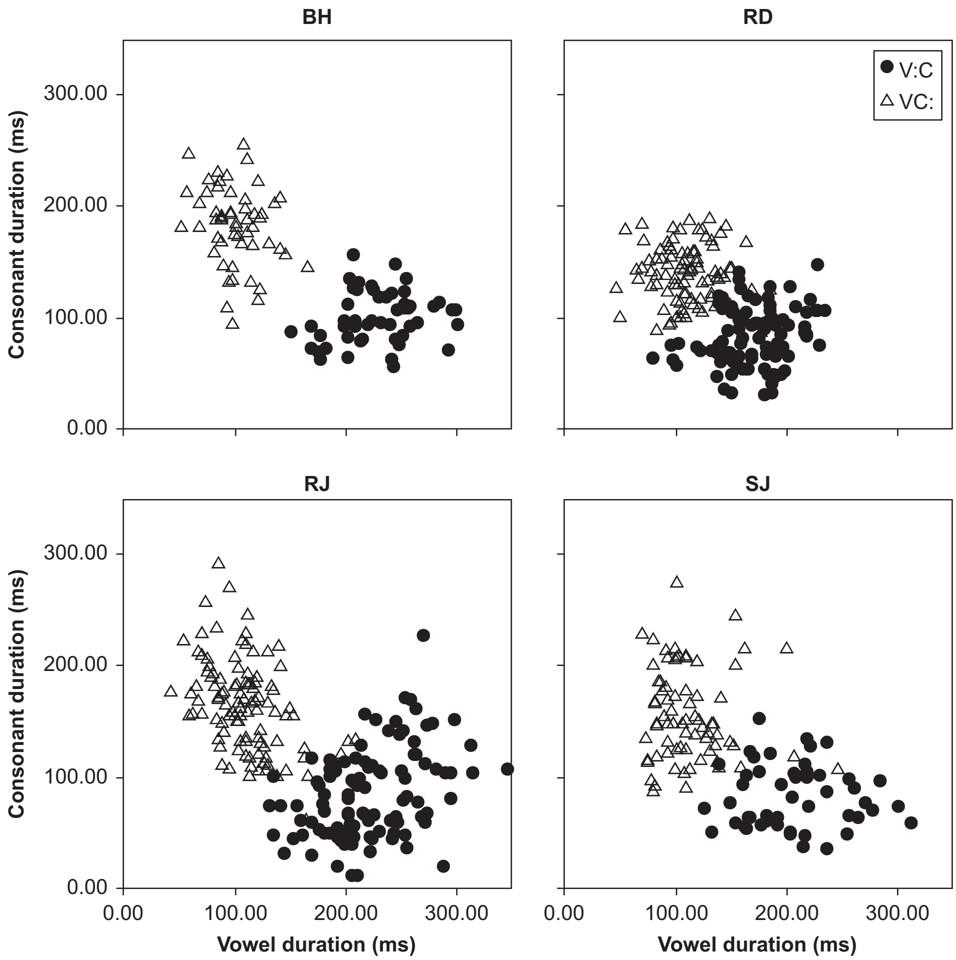


Fig. 1. Relationship between tonic vowel and post-tonic consonant duration for 700 words in Washo arranged by speaker. Data points represent test words. The top two panels represent the production data of BH and RJ, the speakers from the 1950s. The bottom two panels show the production data of RD and SJ, two speakers of the language today.

Table 3

	VC sequence	b	a	*r*	r^2	*F*-statistics
BH	V:C	0.13	74.60	0.20	0.04	(1.52) = 2.07
	VC:	−0.39	225.40	0.26*	0.07	(1.52) = 3.61
RJ	V:C	0.34	14.92	0.37**	0.14	(1.107) = 16.83**
	VC:	−0.58	229.89	0.43**	0.18	(1.102) = 22.59**
RD	V:C	0.19	47.44	0.24**	0.06	(1.96) = 5.68*
	VC:	−0.05	139.45	0.06	0.03	(1.88) = 0.29
SJ	V:C	−0.25	89.13	0.04	0.02	(1.47) = 0.08
	VC:	−0.10	167.19	0.08	0.06	(1.71) = 0.40

*$p < 0.05$.
**$p < 0.01$.

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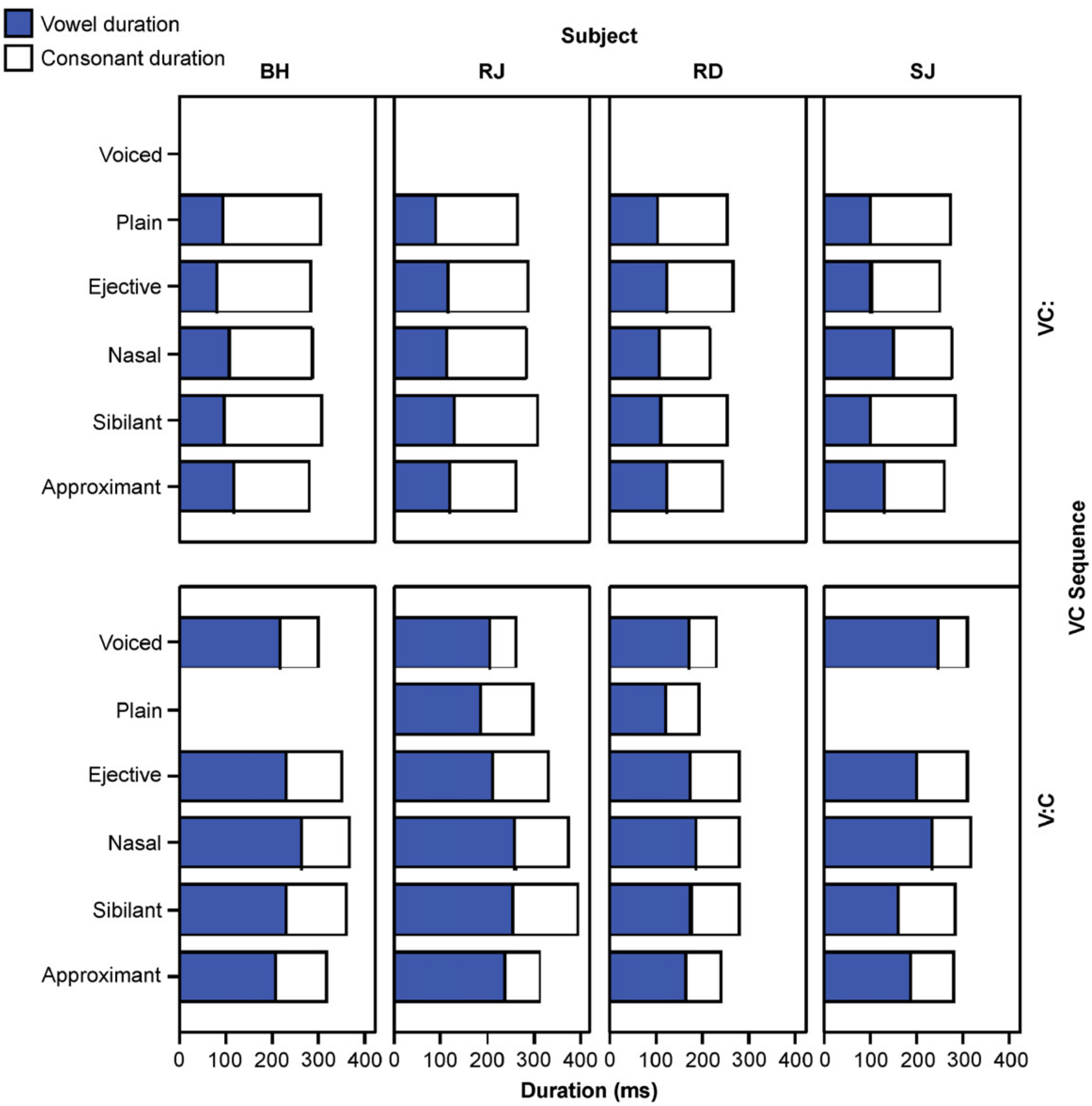

Fig. 2. Mean duration (ms) of tonic vowels and post-tonic consonants in the V:C and VC: types of syllables.

Table 4
Combined mean durations (ms) of tonic vowels and post-tonic consonants

	VC:	V:C	*F*-statistics
BH	288.46	331.32	$F(1.104) = 30.37^{**}$
RJ	279.53	319.06	$F(1.151) = 20.92^{**}$
RD	244.47	246.78	$F(1.160) = 0.13$
SJ	268.25	300.76	$F(1.95) = 11.14^{**}$

Consider now the duration of the post-tonic consonants. Overall, consonants after a short tonic vowel are about 54% longer than consonants after a long tonic vowel. A step-wise linear multiple regression analysis was carried out to determine which properties are good predictors of post-tonic consonant duration. The results of the multiple linear regression analyses are shown in Table 8. Vowel quantity, subject identity, and

Table 5
Mean durations (ms) of long and short vowels and their ratios

Subject	Long vowel	Short vowel	Long vowel/short vowel ratio
BH	227.67	103.60	2.20
RJ	226.12	114.78	1.97
RD	166.78	114.02	1.46
SJ	210.77	113.00	1.87
Average	207.83	111.35	1.87

Table 6
Mean ratios of post-tonic consonant durations in VCː and VːC sequences and results of a series of one-way ANOVA comparing the durations of such post-tonic consonants

	Cː/C ratio			
	BH		RJ	
Sibilant	1.63	$F(1.17) = 50.65^{**}$	1.29	$F(1.23) = 5.47^{*}$
Nasal	1.74	$F(1.23) = 74.99^{**}$	1.48	$F(1.31) = 24.36^{**}$
Approximant	1.50	$F(1.25) = 18.3^{**}$	1.89	$F(1.37) = 45.42^{**}$
Ejective	1.70	$F(1.14) = 53.39^{**}$	1.44	$F(1.20) = 21.20^{**}$
Plain			1.59	$F(1.8) = 18.37^{**}$
	RD		SJ	
Sibilant	1.36	$F(1.24) = 38.34^{**}$	1.51	$F(1.20) = 12.18^{**}$
Nasal	1.20	$F(1.\ 20) = 8.29^{**}$	1.52	$F(1.16) = 48.88^{**}$
Approximant	1.58	$F(1.37) = 38.9^{**}$	1.42	$F(1.16) = 8.14^{*}$
Ejective	1.37	$F(1.23) = 49.20^{**}$	1.32	$F(1.19) = 5.40^{*}$
Plain	2.08	$F(1.20) = 51.73^{**}$		

$^{*}p<0.05$.
$^{**}p<0.01$.

subject generation were significant predictor variables ($p<0.01$) for post-tonic consonant duration ($r^2 = 0.53$). The lack of an effect for vowel duration further strengthens the interpretation that the relationship between vocalic and post-tonic consonantal length is categorical rather than quantitative. The negative coefficient for vowel quantity suggests that there is a negative association between quantity and post-tonic consonant duration. There is also a tendency for the current speakers to have shorter post-tonic consonants than the previous generation of speakers. Among the four speakers, the ranking of mean post-tonic consonant duration from longest to shortest are as follows: BH (145.02 ms) > SJ (132.82 ms) > RJ (128.84 ms) > RD (103.19 ms).

Turning now to the production of individual classes of post-tonic consonants, Table 6 shows the mean ratios (i.e., Cː/C) between the durations of post-tonic consonants in VCː and VːC sequences and the results of a series of one-way ANOVA testing the significance of the difference between the durations of such consonants. The results show that, in accordance with Jacobsen's description, post-tonic sibilants, nasals and approximants following a short stressed vowel, are significantly longer those following a long stressed vowel. On average, a post-tonic sibilant, approximant, or nasal after a stressed short vowel is 51% longer than that after a stressed tonic vowel. The experimental evidence concerning the post-tonic ejectives diverges from Jacobsen's description, however. Post-tonic ejectives in the VCː sequences are significantly longer (by about 46%) than those in the VːC sequences in all four speakers and the result of a one-way ANOVA found this difference to be significant ($F(1.104) = 81.77$, $p<0.01$).

With regard to the plain stops, due to the dearth of examples of plain stops after a tonic long vowel in the corpus, no example of post-tonic plain stops after a long /e/ or long /a/ is found in BH and SJ's recordings.

Only two speakers' recordings, RJ and RD, provide enough data for statistical analysis. Post-tonic plain stops in VCː sequences are significantly longer (by about 84%) than those in VːC sequences for both speakers.

To further examine the durational relationship between tonic vowels and post-tonic consonants, the consonant–vowel (C/V) ratio (Port & Dalby, 1982) for each type of VC sequence is calculated. The results are shown in Table 7. On average, a post-tonic consonant is slightly less than half (C/V ratio = 0.45) as long as a tonic long vowel in a VːC sequence, while a post-tonic geminate is about 50% longer (C/V ratio = 1.53) than a tonic short vowel. The C/V measure also reveals that the relationship between tonic vowel and post-tonic voiced stop is in line with the VːC sequences, rather than the VCː sequences. That is, a tonic vowel is about three times as long as its following voiced stop as the C/V ratio for a voiced stop and its preceding tonic vowel is, on average, 0.33. The mean duration of a tonic vowel before a voiced stop is 198.56 ms, which is about 80% longer than the mean duration of a short tonic vowel (i.e., 111.35 ms). An examination of the distribution of the durational values of tonic vowels before a voiced stop reveals a normal unimodal distribution, suggesting that the observed results are not the artifacts of labeling biases. There is considerably more variation among the C/V values of the VCː group than the VːC group. In particular, there is a tendency for the C/V ratios of the VCː sequences to be smaller in the current speakers' tokens, suggesting that post-tonic geminates are not as long in the current generation of speakers as they were in the previous generation. A step-wise linear multiple regression analysis confirms this suspicion. As shown in Table 8, vowel quantity, subject identity,

Table 7
Consonant-vowel (C/V) ratios across two generations of Washo speakers

C/V ratio		BH	RJ	RD	SJ	Average
VːC	Approximant	0.53	0.32	0.46	0.49	0.45
	Ejective	0.53	0.57	0.61	0.56	0.57
	Nasal	0.39	0.45	0.49	0.37	0.43
	Plain		0.59	0.61		0.60
	Sibilant	0.57	0.56	0.61	0.76	0.62
	Voiced	0.39	0.28	0.38	0.26	0.33
	Average	0.46	0.41	0.49	0.45	0.45
VCː	Approximant	1.43	1.32	1.05	1.01	1.20
	Ejective	2.69	1.53	1.17	1.45	1.71
	Nasal	1.70	1.70	1.02	0.89	1.33
	Plain	2.34	2.07	1.48	1.70	1.90
	Sibilant	2.17	1.49	1.30	1.89	1.71
	Average	1.89	1.56	1.19	1.47	1.53

Table 8
Results of linear multiple regression analysis on vowel duration, consonant duration, and C/V ratio

	Intercept	Significant variables	Regression coefficients	Overall r^2
Vowel duration	51.05	Vowel quantity	96.93	0.67
		Subject	−9.79	
		Consonant type	−4.23	
Consonant duration	236.60	Vowel quantity	−67.48	0.53
		Subject	−11.59	
		Generation	11.49	
C/V ratio	2.531	Vowel quantity	−1.10	0.61
		Subject	−0.10	
		Generation	0.15	
		Consonant type	0.03	

For each measure, the significant predictor variables are shown with their intercept constants, their regression coefficients and the overall r^2 showing model fit.

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consonant type, and subject generation were significant predictor variables ($p < 0.01$) for C/V ratio ($r^2 = 0.61$). The fact that subject generation is a predictive variable suggests that the reduction in C/V ratio of the current generation of Washo speakers is significant.

3. Discussion and conclusion

This study provides the first quantitative study of the phonetic structure of Washo, focusing on the durational properties of stress-induced quantity alternation in the language. The results of this study echo previous studies of syllable-timing and syllable weight as the acoustic evidence shows general matching between phonological representations and phonetic facts. For example, bimoraic vowels are about twice as long as the monomoraic vowels. Moraic consonants are 54% longer than non-moraic consonants. Also significant is that the acoustic evidence confirms Jacobsen's description that sibilants, approximants and nasals are long in post-tonic positions after a short vowel, but are short after a stressed long vowel. Also in consonant with Jacobsen's description, tonic vowels before a voiced stop are always long. The phonetic evidence, however, reveals that, contrary to previous descriptions, ejectives and plain stops also lengthen after short tonic vowels. This finding thus confirms the suspicion raised above that complementary length alternation is much more systemic in the language than is previously reported (Jacobsen, 1964). This conclusion has important ramifications for the understanding of the phonology of the language. As alluded to earlier, the length alternation has been analyzed as the consequence of a systemic requirement for stressed syllables to be phonologically heavy in Washo (Yu, 2005). Post-tonic consonant gemination after short stressed vowels may be viewed as a compensatory response to the monomoraicity of short vowels. Phonological analyses based on previous descriptions would have to stipulate the restricted classes of segments that may geminate. However, the inclusion of ejectives and plain stops within the set of geminatable segments in Washo drastically simplifies the phonological description. The only non-geminating class of segments is the voiced stops, an exception that is in accord with the typology of geminates. That is, cross-linguistically, geminate obstruents are predominantly voiceless. That voiced geminates are often avoided can be explained by the fact that it is aerodynamically difficult to sustain voicing during a long period of closure (Ohala, 1983). There are thus sound phonetic reasons behind the absence of lengthened voiced stops in the language. In regard to the issue of isochrony, the evidence suggests that the duration co-variation of tonic vowel and post-tonic consonant is a categorical phonological matter, rather than a matter of gradience. Tonic vowel quantity, not duration, is a strong predictor of post-tonic consonant length. Thus, isochrony across stressed syllables holds at the moraic level, rather than at the quantitative phonetic level.

The pressure to maintain a heavy stressed syllable in Washo forces the assignment of an extra mora to the stressed syllable when the tonic vowel is underlyingly light. While post-tonic consonant lengthening is the preferred strategy, tonic vowel lengthening is also possible when the post-tonic obstruent is voiced. The preference for post-tonic lengthening over tonic vowel lengthening might be due to the pressure of contrast maintenance (e.g., Flemming, 1995). As noted earlier, vowel length is contrastive in Washo, albeit only in the stressed syllable. Lengthening of a tonic short vowel would obliterate this contrast.

The fact that vowel lengthening is limited to a pre-voiced stop context lends itself to a natural phonetic explanation as well. Cross-linguistically, vowels before voiced, lenis stops tend to be longer than vowels before voiceless, fortis stops. Peterson and Lehiste (1960), for example, found that the ratio of the duration of vowels before voiceless consonants to the duration of the vowels before voiced consonants is about 2:3 in American English. Thus, it is possible that, at the time when the heavy stressed syllable requirement developed, the amount of vocalic lengthening before voiced stops was sufficiently high that certain Washo speakers were not able to reliably differentiate vowel length in that context. As a result, length neutralization emerges.

It should be noted that the contrast maintenance explanation hinges on the claim that vowel length is distinctive in Washo. This interpretation is by no means settled. Due to the mutual predictability of vowel and post-vocalic consonantal length in the stressed syllable, either long vowels or post-vocalic geminate consonants maybe assumed to be underlying. I shall not engage in this thorny debate in the present context and will leave the issues for another occasion. However, it should be mentioned that this indeterminacy is not unique to Washo. There is, for example, a long standing debate concerning the proper characterization of the co-variation of vowel and consonant length in stressed syllables in the Nordic languages (Benediktsson, 1963;

Elert, 1964; Eliasson, 1985; Kristoffersen, 2000; Rice, 2003). Kristoffersen (2000), for example, argues that no long segment needs to be posited underlyingly in Norwegian. Instead, the lexicon is divided arbitrary into two lexical classes. One lexical class satisfies the heavy stressed syllable requirement by way of vowel lengthening, while the other via consonant gemination. Rice (2003), on the other hand, prefers to reconceptualize the relationship between the phonology of a language and its lexicon, thus obligating the analyst to account for the inventory of attested patterns only and not the actual distribution of such patterns.

As alluded to in the introduction, the results of the acoustic study not only demonstrate the phonetic reality of quantity alternation between tonic vowels and post-tonic consonants in Washo, they also illustrate the importance of phonetic studies to research on endangered languages. Some scholars have suggested that a bilingual speaker of a threatened language in a language-contact situation will make fewer phonological distinctions in his or her use of the language than a fully competent (dominant or monolingual) speaker of the same language would (e.g., Andersen, 1982). While the Washo language is generally classified as severely moribund, the current generation of Washo speakers by and large retains the subtle phonetic alternations examined in the present study, despite the fact they mostly grew up bilingual, if not English-dominant. There are, however, signs that their command of Washo phonology is undergoing attrition. For example, the reduction of the degree of post-tonic gemination in the current generation may signal the impending loss of this important cue for quantity alternation in the language. Speaker RD also shows a much reduced long vowel to short vowel ratio, suggesting that the vowel length distinction might also be reducing in her speech. These attritions raise some interesting questions about the effect of endangerment on the phonological system of a language. Will the disappearance of post-tonic gemination obliterate the stress-to-weight generalization that governs much of Washo morpho-phonology or will alternative strategies be employed to maintain the heaviness of stressed syllables (e.g., tonic vowel lengthening)? Answers to these questions clearly hinge on the survival of the language.

This study also highlights the utility of examining archival phonetic records to supplement real time phonetic fieldwork (Tuttle, 2003). Research on a highly endangered language can often times be a risky endeavor. Data elicited from speakers of such languages must be treated with great care and caution, especially in phonetic and phonological studies. Given the likely atypical linguistic histories of speakers of an endangered language (e.g., a shrinking language community or varying degrees of multilingualism), language acquisition may have arrested at the pre-conventional/overgenerative stage or even at the rote/formulaic knowledge stage (Menn, 1989). It is thus often difficult to ascertain how representative the data is of the language in active use, especially in a situation where the language is seldom used today. By comparing archival phonetic evidence with data from present day phonetic fieldwork, a quantitative evaluation of the extent of change (or the lack thereof) that might have taken place in the language is possible. Thus, for example, in the present study, it is found that quantity alternation extends to the classes of ejectives and plain stops. If one were to take the previous description at face value, one might be inclined to conclude that: (i) the surviving speakers of Washo have extended a previously restricted phenomenon of quantity alternation in sibilants, approximants, and nasals to ejectives and plain stops and that (ii) this may be taken as a possible symptom of language endangerment. Such conclusions are obviously unwarranted in light of the phonetic evidence based on the data retrieved from the audio recordings made in the 50s when the last major effort in documenting the language was done. Archival phonetic records thus offer a rich and important source of information for phoneticians and linguists who are interested in documentary linguistics, the linguistics of language endangerment, and language change. Quantitative evidence from archival phonetic records may not only confirm earlier descriptions, it also prevents modern-day analysts from drawing unwarranted conclusions about languages, endangered or otherwise, based on impressionistic information from earlier descriptions.

As a final note, it is worth mentioning that the present study made extensive use of archived audio recordings. Note, however, that this is only one of many possible resources that are available in the archival records. Adopting the latest phonetic tools and instrumental techniques of the time, many early field linguists (e.g., Franz Boas, J.P. Harrington, Alfred Kroeber, Pliny E. Goddard, Edward Sapir, & T. Waterman) incorporated empirical measurements and methodologies into their study of the linguistic systems of Native American languages (e.g., Goddard, 1904, 1905, 1912). These techniques not only included audio recording, but also kymograph, photography, and even palatography. In the context of the linguistic study of Native

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American languages, many of which are endangered, such phonetic records can provide valuable supplemental resources for descriptive phonetic study and the study of phonetic change.

Acknowledgments

Earlier versions of this project were presented at BLS 31 and at the 2006 annual meeting of the Linguistic Society of America, Albuquerque, New Mexico. I am grateful for helpful discussion from audience members at these events. Many thanks to the three anonymous reviewers and the guest editors of this special issue for their helpful and constructive comments and suggestions. Last but not least, special thanks go to Washo elders for sharing their knowledge of the language with me. Much of this research would not be possible without their generous support and patience. I would also like to thank Professor William Jacobsen Jr. for granting me access to his field recordings from the 1950s. Portions of this work were supported by NSF Grant #0553675.

References

Andersen, R. W. (1982). Determining the linguistic attributes of language attrition. In R. D. Lambert, & B. F. Freed (Eds.), *The loss of language skills*. Rowley, MA: Newbury House Publishers.

Benediktsson, H. (1963). The non-uniqueness of phonemic solutions: Quantity and stress in Icelandic. *Journal of Phonetics*, *10*, 133–153.

Boersma, P., & Weenink, D. (1996). *PRAAT*: *A system for doing phonetics by computer*, *version 3.4*. Rapport no. 132, Instituut voor Fonetische Wetenschappen, Universiteit van Amsterdam.

Borrelli, D. A. (2000). *Raddoppiamento sintattico in Italian*: *A synchronic and diachronic cross-dialectal study*. Unpublished Ph.D., Cornell University, Ithaca.

Broselow, E., Chen, S.-I., & Huffman, M. (1997). Syllable weight: Convergence of phonology and phonetics. *Phonology*, *14*(1), 47–82.

Campbell, L., & Mithun, M. (Eds.). (1979). *The languages of native America: Historical and comparative assessment*. Austin: University of Texas Press.

Dixon, R., & Kroeber, A. L. (1919). Linguistic families of California. *UCPAAE*, *16*, 47–118.

Duanmu, S. (1994). Syllabic weight and syllable durations: A correlation between phonology and phonetics. *Phonology*, *11*, 1–24.

Elert, C.-C. (1964). *Phonologic studies in quantity in Swedish*. Uppsala: Almqvist & Wiksells.

Eliasson, S. (1985). Stress alternations and vowel length: New evidence for an underlying nine-vowel system in Swedish. *Nordic Journal of Linguistics*, *8*, 101–129.

Flemming, E. S. (1995). *Auditory representations in phonology*. Unpublished Ph.D., University of California, Los Angeles, Los Angeles.

Goddard, P. E. (1904). *Hupa tracings*: *Typescript*, *1904*. Ethnological documents of the Department and Museum of Anthropology, University of California, Berkeley.

Goddard, P. E. (1905). Mechanical aids to the study and recording of language. *American Anthropologist*, *III*, 613–619.

Goddard, P. E. (1912). *Texts and analysis of Gold Lake dialect, Chipewyan*. New York: The Trustees.

Gordon, M. (1999). *Syllable weight*: *phonetics*, *phonology*, *and typology*. Unpublished Ph.D., University of California, Los Angeles, Los Angeles.

Gordon, M. (2004). Syllable weight. In B. Hayes, D. Steriade, & R. Kirchner (Eds.), *Phonetic bases for phonological markedness* (pp. 277–312). Cambridge: Cambridge University Press.

Harms, R. T. (1966). Stress, voice and length in Southern Paiute. *International Journal of American Linguistics*, *32*(3), 228–235.

Harrington, J. (1917). Announcement of genetic relationship between Washo and Chumashan. *American Anthropologist*, *19*, 154.

Hubbard, K. (1995). 'Prenasalized consonants' and syllable timing: Evidence from Runyambo and Luganda. *Phonology*, *12*, 235–256.

Jacobsen, W. H. J. (1964). *A grammar of the Washo language*. Unpublished Ph.D., University of California, Berkeley, Berkeley.

Jacobsen, W. H. J. (1996). *Beginning Washo*. Carson City, Nevada: Nevada State Museum.

Kiparsky, P. (to appear). Fenno-Swedish quantity: Contrast in Stratal OT. In B. Vaux (Ed.), forthcoming.

Kristoffersen, G. (2000). *The phonology of Norwegian*. Oxford: Oxford University Press.

Leyden, K. V. (2002). The relationship between vowel and consonant duration in Orkney and Shetland dialects. *Phonetica*, *59*, 1–19.

Liu, F., & Xu, Y. (2003). Underlying targets of initial glides: Evidence from focus-related F0 alignments in English. In *The 15th international Congress of phonetic sciences* (pp. 1887–1890), August, 2003, Barcelona, Spain.

McDonough, J., & Austin-Garrison, M. (1994). *Vowel enhancement and dispersion in the vowel space of Western Navajo*: *A study of traditional Navajo speakers*. University of California working papers in phonetics (pp. 93–104), 87, August 1994.

McRobbie-Utasi, Z. (1999). *Quantity in the Skolt* (*Lappish*) *Saami language*: *An acoustic analysis* (Vol. 165). Bloomington, Indiana: Indiana University Research Institute for Inner Asian Studies.

Menn, L. (1989). Some people who don't talk right: Universal and particular in child language, aphasia, and language obsolescence. In N. Dorian (Ed.), *Investigating obsolescence: Studies in language contraction and death* (pp. 335–345). Cambridge: Cambridge University Press.

Ohala, J. J. (1983). The origin of sound patterns in vocal tract constraints. In P. F. MacNeilage (Ed.), *The production of speech* (pp. 189–216). New York: Springer.

Peterson, G. E., & Lehiste, I. (1960). Duration of syllable nuclei in English. *Journal of Acoustical Society of America*, *32*, 693–703.

Pind, J. (1999). Speech segment durations and quantity in Icelandic. *Journal of Acoustical Society of America*, *106*(2), 1045–1053.

Port, R. F., & Dalby, J. (1982). Consonant/vowel ratio as a cue for voicing in English. *Perception & Psychophysics*, *32*(2), 141–152.

Rice, C. (2003). *Norwegian quantity and the richness of the base*. Unpublished manuscript, Tromso.

Sapir, E. (1917). The status of Washo. *American Anthropologist*, *19*, 449–450.

Sapir, E. (1921). A supplementary note on Salinan and Washo. *International Journal of American Linguistics*, *2*, 68–76.

Sapir, E. (1930). The Southern Paiute Language: Southern Paiute, a Shoshonean language. *Proceedings of the Academy of Arts and Sciences*, *65*(1), 1–296.

Tuttle, S. G. (2003). Archival phonetics: Tone and stress in Tanana Athabaskan. *Anthropological Linguistics*, *45*(3), 316–336.

Woodbury, A. C. (1985). Graded syllable weight in Central Alaskan Yupik Eskimo (Hooper Bay-Chevak). *International Journal of American Linguistics*, *51*(4), 620–623.

Xu, Y., & Liu, F. (2002). Segmentation of glides with tonal alignment as reference. In *Proceedings of the seventh international conference on spoken language processing* (pp. 1093–1096), September 2002, Denver, Colorado.

Yu, A. C. L. (2005). Quantity, stress, and reduplication in Washo. *Phonology*, *22*(3), 437–475.

Yu, A. C. L. (to appear). Prosodically-governed segmental fission in Washo. In R. Cover, & Y. Kim (Eds.), *The proceedings of the 31st annual meeting of the Berkeley Linguistics Society*.

Please cite this article as: Yu, A. C. L. The phonetics of quantity alternation in Washo. *Journal of Phonetics* (2008), doi:10.1016/j.wocn.2007.10.004