Vowel length in Niuean

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Abstract

At the surface level, Niuean has a three-way distinction between vowels of the same quality: short vowels written as <a>, double vowels (or rearticulated vowels) written as <aa>, and long vowels written as <ā>. While the Polynesian literature suggests that the distinction between long and double vowels is one based on stress assignment, little evidence has been presented to support such a claim for Niuean. This paper presents a series of arguments on how best to understand the status of Niuean vowels. We argue that double and long vowels are reducible to an underlying sequence of two identical short vowels and support this analysis with two main pieces of evidence: a corpus of words in Sperlich (1997) show long vowels and double vowels to be in complementary distribution, and phonetic analyses of Niuean words suggest that the phonetic difference between long and double vowels can best be captured in terms of pitch height rather than duration, a main correlate of stress.

1. Introduction

Niuean belongs to the Polynesian language within the Austronesian phylum, spoken on the island of Niue, and also widely spoken in New Zealand[2]. At a surface level, Niuean has a three-way distinction between vowel types of the same quality, reflected in the writing system of the language: short vowels written as <a>, long vowels written as <ā>, and double vowels (or rearticulated vowels) written as <aa> (Polinsky 1995, Sperlich 1997). Sperlich (1997:4) defines rearticulation as “the separate pronunciations of the vowels in a vowel sequence.” Examples of these vowels types are given in (1).

(1) Three-way surface distinction in vowel types

a.	Short	<a>:	afua ‘fine’
b.	Long	<ā>:	āfou ‘adze’
c.	Double	<aa>:	aafu ‘to be hot’

Sperlich (1997:6) notes that “there is good historical evidence which supports double vowel sequences being the result of intervocalic consonant loss”. Examples include possessives *haau*, *haaku*, and *haana* where the double vowels result from loss of an intervocalic glottal stop (cf. Tongan *ha’au, ha’aku,* and *ha’ana*), as well as other intervocalic consonant elision (e.g. Proto-Polynesian *maaqoli > Niuean *mooli* ‘true’).

These historical processes have had consequences across the Polynesian languages on vowel length and on the assignment of stress and there has been considerable debate as to how to accurately describe that relationship (see Krupa (1982:27-29), as well as Schütz (1999:148) for both Polynesian and Fijian). Biggs (1971:469) provides a very broad statement, claiming that “contrastive vowel length” across Polynesia as a whole is better analysed as “geminate clustering.” Krupa (1973:52) states that long vowels in Polynesia are “preferably treated as sequences of two identical vowels, [making] the prediction of stress simpler,” and Clark (1974:103fn4) claims that “the stress systems of most Polynesian languages are essentially of the same type,” if we consider long vowels better analysed as vowel-vowel sequences (also cited by Schütz 2001:311).

Many statements have been made for individual Polynesian languages, as well. Feldman (1978), De Chene (1985:84-88), Poser (1985:266), Taumoefolau (2002), and Anderson and Otsuka (2006) all claim that vowel length in Tongan is best treated as a phonetic realization of two short vowels, rather than being phonologically contrastive. Taumoefolau (2002) in particular lays out in detail how long and double vowels result from interactions with the stress algorithm of the language. Similar analyses treating long vowels as consisting of two short vowels have been put forward for Polynesian languages Maori (Williams 1917, cited in Schütz 1985:11; Krupa 1968:27; Bauer 1993:534-37), Samoan (Pawley 1966:5; Hovdhaugen 1990:95), Rennellese-Bellonese (Elbert 1975), Tuvaluan (Besnier 2000:612-13), and Vaeakau-Taumako (Næss & Hovdhaugen 2011:27-28), and also Fijian (Scott 1948), closely related to Polynesian.

Previous statements of the relationship between double vowel and long vowels, and also vowel type and stress have been made for Niuean, as well. McEwen’s (1970) *Niuean dictionary* describes double vowels as occurring when the stress falls on the

[2] The current estimate of the Niuean ethnic population is 1,611 in Niue, and 20,200 in New Zealand (Statistics Niue 2012). Previous Niuean-speaking populations were estimated to be 1,230 in Niue and 5,481 in New Zealand (Siosikefu and Haberkorn 2008; New Zealand Ministry of Education 2009).

second vowel of an identical vowel-vowel sequence (e.g. *haaku*, *moota*, etc.). Further, Seiter (1980:35) remarks on instances of allomorphic variation between long and double vowels, noting that "rearticulated aa in singular possessive pronouns becomes long ā, and the absolutive marker e may fail to appear when this rule has applied" (underlining his), as in (2) with *haaku* ~ *hāku* 'my'.

(2) Variation between long and double vowels[3]

a.

e	kulī	haaku	
ABS	dog	my	

'my dog, a dog of mine'

b.

(e)	hāku	a	kulī
ABS	my		dog

'my dog'

Similar systematic variation is also later described in Sperlich (1997:264), noting that "the rearticulated ee in *peehi* ['to press, push down'] changes to a long ē when suffixed," and also in Sperlich (2000:388) who notes a basic distinction of short vs. long/double, which are in complementary distribution (citing communication with Bruce Biggs). Previous authors were also aware of the limited distribution of double vowels (e.g. Sperlich 2000:384), noting the fact that double vowels have a limited distribution and never word initially or finally.

In this paper, we look at the distribution of long and double vowels in the main entries in Sperlich's (1997) *Tohi vagahau Niue – Niue language dictionary* for evidence in support of the claims of the stress-based distribution of Niuean long and double vowel types. We discovered only a handful of counterexamples and these could be explained through historical morpheme boundaries and variability in the pronunciation of such forms. Further, the distribution of long and double vowels within Niuean loan words mirrored the distribution within native vocabulary, suggesting a systematic grammatical principle at work governing the adaptation of foreign input.

We also recorded one speaker producing a small number of words containing short, long, and double vowels in contexts derived from Sperlich's dictionary, measuring duration and pitch. Our findings show that while short vowels are consistently distinguished from long and double vowels by duration, long vowels and double vowels are consistently distinguished from one another by pitch profiles rather than duration. We interpret the pitch data here as being the phonetic correlate of phonological stress.

The two pieces of evidence support an analysis treating long vowels and double vowels as surface variants of underlying $/V_iV_i/$ sequences consisting of identical adjacent short vowels which are conditioned by the assignment of primary stress within a phonological word. A long vowel surfaces when primary stress falls on the initial vowel of this sequence ($\acute{V}_iV_i$), which undergoes what we understand to be syllable fusion following Poser (1985). This syllable fusion process results in a long vowel $[V_i{:}]$ <$\bar{V}$>. In contrast, a double vowel surfaces when stress falls on the second vowel of this sequence ($V_i\acute{V}_i$). Thus the two vowel types are in complementary distribution and both derive from underlying short vowel sequences, as is common in many Polynesian languages.

[3] The abbreviation ABS stands for "Absolutive case."

This paper is structured as follows. In section 2, we lay out the Niuean vowel types short, long, and double, and show how they are derived from primary stress assignment and provide a description of this process. We also provide our theoretical foundations here, and show how the distribution of long vowels in Niuean (and also to some extent, Tongan) differ other Polynesian languages, such as Hawaiian. In sections 3 and 4, we provide our main pieces of evidence for our analysis, consisting of our Niuean dictionary survey and our phonetic study. In section 5, we briefly touch on an issue outside of the scope of this paper, namely secondary stress. We conclude this paper with a small note on the potential implications inherent instabilities in vowel types and stress patterns may have for the teaching of Niuean language and literacy.

2. Niuean vowel types and stress

The Niuean vowel system is characterised as a classic five quality system /i e a o u/, with a three way surface distinction between short <i e a o u>, long <ī ē ā ō ū>, and double vowel <ii ee aa oo uu> types (McEwen 1970, Seiter 1980, Sperlich 1997), shown in (3)[4].

(3) Vowel types in Niuean

a.	Short:	ota	'to eat raw'
b.	Long:	ōtai	'drink of coconut'
c.	Double:	ooki	'to rest for a short time'

There are two possible analyses for the vowels. The first possibility is that the orthographic representation is phonemic. Polinsky (1995:19) provides limited evidence for one potential three-way minimal pair, shown in (4) below.

(4) Potential three-way minimal pair evidence in Niuean [not supported in our analysis] (Polinsky 1995:19)

a.	Short:	ulu 'head' (голова)
b.	Long:	u:lu 'smite, destroy' (разрушать) [play the devil]
c.	Double:	uulu 'to put out' (вытянуть)

We have not been able to replicate such a three-way distinction in any other source, nor through our own recordings with speakers. The relative absence of such evidence would suggest the more popular second position, namely that short vowels are represented as an underlying short vowel /V_i/ and that both long and double vowels are represented as an underlying sequence of two identical vowels /V_iV_i/, and are therefore phonologically equivalent. Under this analysis, long vowels are not "true" phonological long vowels, but rather contextual variants of certain short vowel sequences. These two possible analyses are illustrated in (5).

[4] With respect to other parts of Niuean phonology, the Niuean consonantal system consists of a series of voiceless stops /p t k/, three fricatives /f v s/, three nasals /m n ŋ/ (/ŋ/ is represented as <g>), a liquid represented as /l/, and the glottal consonant /h/. The semi-vowels [w y] are vocalic in nature and only appear at syllable onsets. Sperlich (1997:9) notes that codas and consonant clusters do not exist, and that root words are typically "mono-, di- or trisyllabic."

(5) Two potential analyses of Niuean long vowels

Phonological Long Vowels			Allophonic Long Vowels		
$/V_i/$	$/V_i{:}/$	$/V_iV_i/$	$/V_i/$	$/V_iV_i/$	
|	|	|	|		
$[V_i]$	$[V_i{:}]$	$[V_iV_i]$	$[V_i]$	$[V_i{:}]$	$[V_iV_i]$
Short	Long	Double	Short	Long	Double

In this paper, we adopt the second allophonic analysis, and point to the Niuean stress algorithm as the conditioner on vowel type distribution[5].

In order to consider long and double vowels in the Niuean dictionary, we must first gain a preliminary understanding of stress in Niuean. Canonical primary stress is widely acknowledged as falling on the penultimate syllable of words in Niuean (e.g. Sperlich 1997), and is therefore predictable and not necessary to specify in the underlying representation. However, Sperlich (1997:10) also describes primary stress as falling on a final (i.e. ultimate position) long vowel, thus requiring two statements for the location of primary stress. Under the allophonic interpretation, we can unify these two statements with the stress algorithm shown below, illustrated with the words *iina* 'to frighten someone', *fitā* 'to have already done something', and *pēkau* 'wing' in (6). This algorithm enables us to divide Niuean stress assignment with respect to short, long, and double vowels into a number of steps.

First, each underlying vowel is associated with its own syllable. At this stage, the mora and syllable are coextensive[6]. No syllable is associated with more than two vowel positions, i.e. no underlying heavy syllables/no underlying bimoraic syllables. Within the stress algorithm, the two rightmost syllables form a stress group at the right edge. We borrow the use of the term "stress group" from Taumoefolau (2002); we understand this to be a notational variant of the notions "foot" and "measure" (as used in Schütz 1981, 1985, 1999, 2001).

(6) Stress group formation

(a)	/iina/	(b)	/fitaa/	(c)	/peekau/
	i.(i.na)		fi.(ta.a)		pe.e.(ka.u)

Second, penultimate word stress occurs within this stress group (resulting in a moraic trochee prosodic structure) as illustrated in (7) below.

(7) Penultimate stress

(a)	(x .)	(b)	(x .)	(c)	(x .)
	i.(í.na)		fi.(tá.a)		pe.e.(ká.u)

[5] The analysis we present here is to a large extent also laid out in Rolle's (2009) working paper.

[6] Similar claims equating mora and syllable at some level have been made for Tongan. Anderson and Otsuka (2006:41) claim that long vowels should be considered a sequence of two syllables, and that the syllable and the mora are coextensive, and further, Macdonald (2007:59) has argued that syllables are either "redundant, or they are irrelevant to stress assignment," and that the only prosodic unit necessary is the mora.

Third, where stress falls, determines whether a long or double vowel surfaces, shown in (8). A double vowel surfaces when stress falls on the second vowel of an identical vowel-vowel sequence, as in (8a). In contrast, a long vowel surfaces either when stress falls on the first vowel of an identical vowel-vowel sequence within a stress group as in (8b), or when no clear stress falls on either of the identical vowels as in (8c).

(8) Long/double vowel creation

(a)	i.(í.na)	(b)	fi.(tá.a)	(c)	pe.e.(ká.u)
	[iína]		[fitá:]		[pe:káu]
	<iina>		<fitā>		<pēkau>

Secondary stress is outside of the scope of this paper. We discuss this issue briefly below in section 5.

A consequence of this analysis is that the syllable structure at different stages of stress assignment is different from that at the surface, phonetic level. This is illustrated using the words *kumā* ‘rat’, *gaafi* ‘firewood’, and *mōlī* ‘lamp’ in (9) below[7]. With *mōlī* for example, at the phonetic level there are two syllables [mo:] and [li:], which come from units /mo/, /o/, /li/, and /i/. We understand this non-uniformity between syllable structure at the phonetic and phonological levels as “syllable fusion” (Poser 1985)[8], a process by which two syllables conflate into a single bimoraic syllable.

(9) Non-uniformity between syllable structure at different levels

<table>
<tr><td>Orthographic Word</td><td colspan="6">kumā</td><td colspan="3">gaafi</td><td colspan="4">mōlī</td></tr>
<tr><td>Phonological structure</td><td colspan="6">/kumaa/</td><td colspan="3">/ŋaafi/</td><td colspan="4">/moolii/</td></tr>
<tr><td rowspan="2">Underlying Phonological Position</td><td colspan="2">Ant.</td><td colspan="2">Pen.</td><td colspan="2">Ult.</td><td>Ant.</td><td>Pen.</td><td>Ult.</td><td>>Ant.</td><td>Ant.</td><td>Pen.</td><td>Ult.</td></tr>
<tr><td colspan="2">ku</td><td colspan="2">ma</td><td colspan="2">a</td><td>ŋa</td><td>a</td><td>fi</td><td>mo</td><td>o</td><td>li</td><td>i</td></tr>
<tr><td>Stress Group Formation</td><td colspan="6">ku.(má.a)</td><td colspan="3">ŋa.(á.fi)</td><td colspan="4">mo.o.(lí.i)</td></tr>
<tr><td>Phonetic realization</td><td colspan="6">[kumá:]</td><td colspan="3">[ŋaáfi]</td><td colspan="4">[mo:lí:]</td></tr>
<tr><td>Syllable</td><td colspan="3">ku</td><td colspan="3">ma:</td><td>ŋa</td><td>a</td><td>fi</td><td colspan="2">mo:</td><td colspan="2">li:</td></tr>
<tr><td rowspan="2">Phonetic Syllable Position</td><td colspan="3">σ_2</td><td colspan="3">σ_1:</td><td>σ_3</td><td>σ_2</td><td>σ_1</td><td colspan="2">σ_2:</td><td colspan="2">σ_1:</td></tr>
<tr><td colspan="3">Pen.</td><td colspan="3">Ult.</td><td>Ant.</td><td>Pen.</td><td>Ult.</td><td colspan="2">Pen.</td><td colspan="2">Ult.</td></tr>
</table>

The advantage of this analysis is that we may unify the stress algorithm of the language: stress uniformly falls on the underlying penultimate vowel of a stress group at the

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[7] In this table, abbreviations within the “syllable position” row are as follows: >Ant. = before antepenultimate syllable, Ant. = antepenultimate syllable, Pen. = penultimate syllable, and Ult. = ultimate syllable.

[8] Poser (1985:266) notes with respect to Tongan that when two identical vowels are adjacent, they (1) form a single syllable (i.e. a long vowel) undergoing “syllable fusion,” or (2) “belong to two different syllables” (i.e. a double articulated vowel-vowel sequence). One of the conditions of this fusion is that “stress must not fall on the second of the two vowels.”

phonological level (before syllable fusion). As such, stress does not "fall on" long vowels *per se*, but rather conditions their occurrence in the first place.

Given this stress system sketched above, we expect a complete complementary distribution between long and double vowels within phonological words. Double vowels should be found only before a single monomoraic syllable, e.g. in CV_iV_iCV word types such as *gaafi* 'firewood' above, whereas long vowels should be found in all other positions except this one, i.e. we should not expect to find a word of the structure CV_i:CV.

This contrasts with languages such as Hawaiian where Schütz (1981:19) notes that long vowels occur in surface penultimate syllable position before a single monomoraic syllable with a short vowel – albeit rarely in this position – e.g. *ke kāna*. Further, Schütz puts forward the following four basic syllable types in Hawaiian which are the building blocks of Hawaiian stress groups (C is optional, and v represents the off-glide portion of a diphthong).

(10) Basic syllable types – Hawaiian (Schütz 1981:19)

Type:	CV	CV̄	CVv	CV̄v
Ex.:	*ma*	*lā*	*kai*	*kāi*

Each of these syllable types may occur in surface penultimate position, and receive primary stress in this position, even the latter three multimoraic syllable types, e.g. CVCV́CV [mahálo], CV̄́CV [ú:i], CV́vCV [áia], and CV̄́vCV [ká:ina]. In contrast, for Niuean Sperlich (1997:10) notes that "if a diphthong is in penultimate position (and the word has no final long vowel), the diphthong acquires a rising intonation due to the stress placement," e.g. *fēkouna* 'to send someone to do something' is stressed as [fe:koúna], rather than *[fe:kóuna]. This is in contrast to Hawaiian where stress does not "split" a diphthong, e.g. Schütz (1981:16) notes that *kaina* "kind" has stress on [a], resulting in [káina].

These facts help to show that in Hawaiian, long vowels and diphthongs act as single units which occur independent of stress, and are represented as single units within the underlying representation, therefore being phonemic units of contrast. In contrast, in Niuean, primary stress occurs on the penultimate "mora" of a word uniformly, suggesting that surface long vowels and diphthongs are only later derived through post-stress assignment syllabic fusion, and therefore not phonemic units of contrast.

Our analysis of Niuean rests on a number of theoretical claims within the prosodic literature which capture the difference between Niuean system types and Hawaiian system types. First, we assume that the stress-bearing unit cannot be smaller than the syllable, that is, stress cannot target a sub-constituent of a syllable at the moraic level or representation (Hayes 1995:49-50,120-123,138). Further, we also assume following Hayes (1995:50) that rules of stress group construction (i.e. foot construction) cannot split syllables, which goes at least as far back as Prince's (1976) "principle of syllabic integrity" which states that "the contents of a syllable may not be divided between two metrical units." Because Niuean shows cases in which the second vowel receives the main stress (whose correlate is pitch) – i.e. the double vowel – it follows from these assumptions that they be represented as /VV/ sequences at an early stage in the derivation. If Niuean long vowels were understood as being underlyingly long vowels /V:/, this would be in violation of the assumptions above[9].

3. Niuean dictionary survey

To consider whether such an analysis sketched above could provide an adequate account of long and double vowels, we conducted an exhaustive dictionary survey of lexical items contained in Sperlich's (1997) *Tohi vagahau Niuē - Niue language dictionary*. Our dictionary survey extracted all words, both native and non-native, containing long and double vowels from the main entries of this dictionary, totaling 600/3226 (approximately 19 percent)[10]. Of these words, we found that 592 words (≈ 99 percent) conform to the predicted distribution of long and double vowels based on the assignment of stress, providing crucial empirical support for our analysis. Only 8 words were unpredicted, and many of these show variability in their pronunciation across speakers. Further, some of these exceptional forms contain internal historical morpheme boundaries, suggesting the possibility that these boundaries may still have some effect on how syllables are grouped, effecting prosodic licensing of long and double vowels.

The dictionary entries which we analyse are based on citation forms. As shown in the introduction, variation between a long vowel and a double vowel can occur depending on the lexical word and the morpho-syntactic environment (i.e. whether it forms a single phonological word)[11]. A full analysis of this variation is outside the scope of this present paper.

3.1. Number of long and double vowels

Of the total 600 words with long and double vowels, we note 560 long vowel tokens (instances of a long vowel), and 83 double vowel tokens (instances of a double vowel)[12]. Statistics are provided in the table in (11).

(11) Tokens of Long and Double Vowels

Long vowels	Tokens	Double vowels	Tokens
a:	256	aa	57
e:	77	ee	4
i:	64	ii	7
o:	86	oo	10
u:	77	uu	5
Total	560	Total	83

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[9] For Tongan, counter-analyses exist which do allow a long vowel to be split in this penultimate position, which could be schematized as /CV:CV/ → CVVCV → CV.(V́.CV) → [CV.V́.CV], as argued for in Mester (1992) and Kager (1999:175-177). Kager (1999:177) refers to this process as "vowel breaking" under specific stress conditions. See also Hayes (1995:148)'s discussion of trochaic shortening.

[10] This main entry figure is found in Sperlich (1997:35) under "statistics", totalling 3,226 items. The total number of Niuean entries, however, is 10,173, which includes all derived sub-entries (e.g. *kaiagamena* 'a ceremonial party' derived from *kai* 'to eat').

[11] A full analysis of this variation is outside the scope of this present paper.

[12] We found that most words have only one long or double vowel (558 words). There were 42 words which contained more than one or both of these vowel types.

This table shows that double vowels occur much less frequently than their long vowel counterparts, a ratio of nearly 7:1. Long vowels are more common and occur with relatively equal frequency, except for a disproportionate number of long *ā.* The double vowels *ee, ii, oo,* and *uu* are rare; the double vowel *aa* is more common. This distribution suggests that double vowels have a low functional load in Niuean, apart from *aa*.

3.2. Lack of true minimal pairs.

Our analysis reveals that although surface minimal pairs exist which demonstrate short vs. long vowel contrasts (e.g. *kapa* [kapa] 'to flap (of wings)' and *kapā* [kapa:] 'a shrub plant [*Peperomia pallida*]') and short vs double-vowel contrasts (e.g. *ufi* 'yam' vs. *uufi* 'to cover'), true minimal pairs which differentiate short, long, and double vowels do not exist in this dictionary[13]. Contrasts of vowel types in different word positions did provide surface level contrasts, though were rare and did not occur for all five vowels. We describe the patterns below.

In words consisting only of a single vowel (e.g. the nominal particle *a*) or identical vowel sequence (e.g. the emphatic imperative *ā*), there exists only a contrast between short and long vowels. This is shown in the table in (12). Double vowels do not occur in this context, i.e. no word *aa*. Most instances of such words are grammatical/functional morphemes.

(12) Niuean vowel type surface contrasts in words consisting of only a vowel (sequence)

Vowel type	i	e	a	o	u
Short	i [locative case marker]	e [nominal particle]	a [nominal particle]	-	-
Long	-	ē [vocative particle]	ā [emphatic imperative]	ō 'to go, come' (pl)	-
Double	-	-	-	-	-

In word initial position, near-minimal pairs involving all three vowel types exist for /a/ and /o/ only. Other vowels show pairs only for two of the three types, shown in (13).

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[13] We also were unable to establish a three-way minimal pair in McEwen's (1970) Niuean dictionary.

(13) Niuean vowel type surface contrasts in word initial position

Vowel type	i	e	a	o	u
Short	ihu 'nose'	ea 'to appear (from), emerge'	afua 'fine'	ota 'to eat raw'	ufi 'yam'
Long	-	(ē 'yes')	āfou 'adze'	ōtai 'drink of coconut'	-
Double	iihi 'to split lengthwise'	-	aafu 'to be hot'	ooki 'to rest for a short time'	uufi 'to cover'

A fuller range of near-minimal contrasts is found in word medial position for all five vowel qualities, shown in (14).

(14) Niuean vowel type surface contrasts in word medial position

Vowel type	i	e	a	o	u
Short	kite 'to see, learn, know, understand'	peka 'to tie up a crab'	takape 'widow'	koki 'to limp, to walk on toes'	tutu 'a slide'
Long	kītā 'guitar' [loan]	pēkau 'wing'	tākai 'to rub with oil'	kōkio 'a reef fish, beardfish'	tūtū 'to cut up, chop'
Double	siisi 'cheese' [loan]	peehi 'to press, to push down'	taaki 'to tie up a crab'	hooku '1st SG POSS' [archaic]	tuula 'pulpit'

In word final position, double vowels do not occur in this context entirely, shown in (15).

(15) Niuean vowel type surface contrasts in word final position

	i	e	a	o	u
short	puhi 'to blow'	pake 'Portuguese man-of-war'	kapa 'to flap wings'	koko 'to suffer from something being stiff'	paku 'to be dry, unkempt'
long	puhī 'blow hole (of the sea)'	pakē 'to make a light crackling sound'	kapā 'type of shrub plant'	kokō 'to vomit'	pakū 'to roar, rumble'
double	-	-	-	-	-

These tables show that there are no instances in Sperlich's dictionary which provide conclusive evidence of a functioning three-way vowel contrast in Niuean, and further that the distribution of vowel types is not symmetrical.

3.3. Distribution of long and double vowels

Our dictionary survey extracted all words, both native and non-native, containing long and double vowels from the main entries of this dictionary, totalling 600/3226 (approximately 19 percent). Each of these 600 words was characterized with its syllabic structure, and as a CV template. For example, *fitā* 'to have already done something' can be represented with $[\sigma\underline{\sigma_i:}]$ and $[CVC\underline{V_i:}]$ and *pēkau* 'wing' with $[\underline{\sigma_i:}\sigma\sigma]$ and $[CV_i{:}CV(C)V]$, whereas *iina* 'to frighten someone' can be represented as $[\sigma_i\sigma_i\sigma]$ and $[(C)\underline{V_i}\underline{V_i}CV]$. Further, from our stress algorithm we predict to never find certain structures which are not able to be derived. These include templates $*[\underline{\sigma_i:}\sigma]/*[C\underline{V_i:}CV]$ where a long vowel is followed by a single monomoraic syllable, $*[\sigma\underline{\sigma_i}\underline{\sigma_i}]/*[CVC\underline{V_i}\underline{V_i}]$ where a double vowel appears at the end of a word, and $*[\underline{\sigma_i}\underline{\sigma_i}\sigma\sigma]/*[C\underline{V_i}\underline{V_i}CVCV]$ where a double vowels is followed by two moras (two monomoraic syllables, or one bimoraic syllable). This is precisely what we find.

Below, the word templates are analysed first considering only those words which contain one long or one double vowel, which represent the majority of words within our survey (558/600). The table in (16) provides the results from the dictionary survey, showing that virtually all words containing long and double vowels conform to our predictions (551/558). The overwhelming majority of long vowels appear in surface antepenultimate and ultimate syllables, followed by 0 or 2 surface syllables, whereas the overwhelming majority of double vowels appear in surface antepenultimate-penultimate syllable positions, followed by 1 syllable. There were only 7 irregular and unpredicted words in this subgroup (7/558), described in section 3.5 below. The cells containing irregular forms are shaded grey in (16) below.

(16) Distribution of words containing a single long or double vowel (N = 558)

Vowel Type		Distribution			
Long (N = 477)	Surface Position	Pre-antepenultimate	Antepenultimate	Penultimate	Ultimate
		Before 3 syllables	Before 2 syllables	Before 1 syllable	Before 0 syllables
	Example	tēpunua ‘naughty kid’	pēkau ‘wing’	kaiālu ‘to curse someone’	fitā ‘to have already done something’
	Structure	[… $\underline{\sigma_i:}\sigma\sigma\sigma$] [… $C\underline{V_i:}CVCVCV$]	[… $\underline{\sigma_i:}\sigma\sigma$] [… $C\underline{V_i:}CVCV$]	[… $\underline{\sigma_i:}\sigma$] [… $C\underline{V_i:}CV$]	[… $\underline{\sigma_i:}$] [… $CVC\underline{V_i:}$]
	Words	19	167	2	289
Double (N = 81)	Words	1	4	76	0
	Structure	[… $\underline{\sigma_i\sigma_i}\sigma\sigma\sigma$] [… $C\underline{V_iV_i}CVCVCV$]	[… $\underline{\sigma_i\sigma_i}\sigma\sigma$] [… $C\underline{V_iV_i}CVCV$]	[… $\underline{\sigma_i\sigma_i}\sigma$] [… $C\underline{V_iV_i}CV$]	[… $\underline{\sigma_i\sigma_i}$] [… $CVC\underline{V_iV_i}$]
	Example	fakaatukehe ‘to worry’	fakaaue ‘thank you’	iina ‘to frighten someone’	-
	Surface Position	Before 3 syllables	Before 2 syllables	Before 1 syllable	Before 0 syllables
		>Ant. + >Ant.	>Ant. + Ant.	Ant. + Pen.	Pen. + Ult.

Furthermore, 42/600 words in our survey contained more than one long or double vowel, summarized in (17). In these words, there were long and double vowels which occurred in syllables which did not contain primary stress. Virtually all of these forms were as expected. The only exception was the unexpected form maataata ‘to be dawn’ [$\underline{\sigma_i\sigma_i\sigma_j\sigma_j}\sigma$]/[$CV_iV_iCV_iV_iCV$] (not written as <mātaata>). An explanation for this exception is provided in section 3.5 below.

(17) Distribution of words containing more than one long or double vowel (N = 42)

Vowel Type	Attested Template	Words	Example
Long (N = 41)	[$\underline{\sigma_i:}\underline{\sigma_i:}$] [$C\underline{V_i:}C\underline{V_i:}$]	36	pēpē ‘to scrape’
	[$\underline{\sigma_i:}\sigma\underline{\sigma_i:}$] [$C\underline{V_i:}CVC\underline{V_i:}$]	2	gaīgaī ‘sound of a bird’s wings when flying’
	[$\underline{\sigma_i:}\sigma\sigma\underline{\sigma_i:}$] [$C\underline{V_i:}CVCVC\underline{V_i:}$]	1	tēlakohā ‘meconium’
	[$\underline{\sigma_i:}\underline{\sigma_i:}\sigma\sigma$] [$C\underline{V_i:}C\underline{V_i:}CVCV$]	1	māmāui ‘to be rude, careless’
	[$\underline{\sigma_i:}\underline{\sigma_i:}\underline{\sigma_i:}$] [$C\underline{V_i:}C\underline{V_i:}C\underline{V_i:}$]	1	pāpātī ‘to be on a slope’
Double (N = 1) [Irregular]	[$\underline{\sigma_i\sigma_i\sigma_j\sigma_j}\sigma$] [$C\underline{V_iV_i}C\underline{V_jV_j}CV$]	1	maataata ‘to be dawn’

In total, these dictionary data show overwhelmingly support for the analysis of long and double vowels as surface allophones of the same underlying /V_iV_i/ sequence, conditioned by the placement of primary stress.

3.4. Niuean loanwords

Within our dictionary survey above, we included both native words and non-native loanwords[14]. Of these 600 words surveyed, 94 loanwords were loanwords which contained either a long or double vowel. Of these 94 words, 88 contained a long vowel, while 6 contained a double vowel[15]. These findings are shown in the table in (18)[16].

(18) Table: Loanwords containing one long or double vowel (N = 94)

Vowel type	Position	Words	Niuean word shape	Example: English	Example: Niuean	Example: Stress group
Long vowels (N = 88)	Pre-Ant.	1	[$\underline{\sigma_i}$:σσσ] [C$\underline{V_i}$:CVCVCV]	‘parsnip’ [pɐ:snɨp]	pāsinipi [pa:sinipi]	pa.a.si.(ní.pi)
	Ant.	46	[…$\underline{\sigma_i}$:σσ] […C$\underline{V_i}$:CVCV]	‘garlic’ [gɐ:lɨk]	kāliki [ka:liki]	ka.a.(lí.ki)
	Pen.	0	[…$\underline{\sigma_i}$:σ] […C$\underline{V_i}$:CV]	-	-	-
	Ult.	37	[…$\underline{\sigma_i}$:] […C$\underline{V_i}$:]	‘crowbar’ [kɹɐʉbɐ:]	kolopā [kolopa:]	ko.lo.(pá.a)
	Pen. + Ult.	4	[$\underline{\sigma_i}$:$\underline{\sigma_i}$:] [C$\underline{V_i}$:C$\underline{V_i}$:]	‘cargo’ [kɐ:gɐʉ]	kākō [ka:ko:]	ka.a.(kó.o)
Double vowels (N = 6)	Pre-Ant-Pre-Ant.	0	[$\underline{\sigma_i}\underline{\sigma_i}$σσσ] [C$\underline{V_i}\underline{V_i}$CVCVCV]	-	-	-
	Pre-Ant.-Ant.	0	[$\underline{\sigma_i}\underline{\sigma_i}$σσ] [C$\underline{V_i}\underline{V_i}$CVCV]	-	-	-
	Ant. - Pen.	6	[$\underline{\sigma_i}\underline{\sigma_i}$σ] [C$\underline{V_i}\underline{V_i}$CV]	‘farm’ [fɐ:m]	faama (*fāma) [faama] (*[fa:ma])	fa.(á.ma) *(fá.a).ma
	Pen.-Ult.	0	[…σ$\underline{\sigma_i}\underline{\sigma_i}$] […CVC$\underline{V_i}\underline{V_i}$]	-	-	-

None of the loan words shows exceptional surface syllable structure, revealing a distribution identical to that of native words.

For explicitness, we exemplify how long vowels are maintained and lost depending on stress placement with three examples *kāliki* ‘garlic’, *sikā* ‘cigar’, and *faama* ‘farm’ in (19) below. All of these examples correspond to a long [ɐ:] vowel in the English

[14] We only included those English loanwords which were not designated as a Biblical borrowing (e.g. *Sātukaio* ‘Sadducee, a member of a Jewish group’). Earlier studies on loanwords in Polynesian influencing our analysis include Schütz (2001:314) and Taumoefolau (2002).

[15] Loanwords with double vowels are *faama* ‘farm, *maaka* ‘marker, to mark’, *paama* ‘palm tree’, *paani* ‘frying pan’, *siisi* ‘cheese’, and *uaafo* ‘wharf’.

[16] In this table, we provide an approximation of current NZ English here, and note that pronunciations were different at the period(s) of borrowing. We do not include non-relevant phonetic information.

input. With the first two examples *kāliki* and *sikā*, the underlying vowel-vowel /aa/ sequence occurs in an environment which licenses syllable fusion resulting in a long vowel, and consequently exhibiting long vowel faithfulness. In contrast in the third example *faama*, because the long vowel in English [fɐ:m] ‘farm’ corresponds to a double vowel in a CV_iV_iCV context (i.e. /faama/), the /aa/ sequence is received stress on the second [a], and consequently syllable fusion is not licensed. This is represented as a double vowel in the orthography, <faama>[17].

(19) Correspondence of English long vowels to Niuean long and double vowels

English Input	Long vowel – [ɐ:]		
	‘farm’ [fɐ:m]	‘garlic’ [gɐ:lɨk]	‘cigar’ [sɨgɐ:]
	↓	↓	↓
Niuean phonological form (with epenthesis)	/faama/	/kaaliki/	/sikaa/
Stress Group formation	fa.(a.ma)	ka.a.(li.ki)	si.(ka.a)
Penultimate stress	fa.(á.ma)	ka.a.(lí.ki)	si.(ká.a)
Phonetic form (with syllable fusion)	[faáma]	[ka:líki]	[siká:]
Vowel type	Double	Long	Long
Orthographic form	<faama>	<kāliki>	<sikā>

These data reveal that a foreign input long vowel will be mapped to a long vowel or a double vowel depending on the surrounding environment, illustrating the complementarity of long and double vowel types, and suggesting an identical phonological representation.

3.5. Irregular forms

As shown in section 3.3 above, of the 600 words we surveyed which contained a long or double vowel, only 8/600 did not comply with our predictions based on stress assignment. In these cases, our analysis predicts a long vowel or a double vowel, but instead the attested form contains the opposite in Sperlich’s (1997) dictionary. These words are provided in (20).

(20) Words with unexpected locations of long and double vowels – 8/600

Double	Long
<fakaaue> ‘thank you’	<kaiālu> ‘to curse someone’
<fakaalofa> ‘to love/hello’	<pēa> ‘thus, like this’
<fakapaakau> ‘to pretend to be helpful’	
<fakaatukehe> ‘to worry’	
<maataata> ‘to be dawn’	
<ulaafia> ‘to be uncontrollable’	

[17] In this part of the study, we only compiled loanwords which contain a long or double vowel. In many instances, however, a long vowel in English corresponds to a short vowel in Niuean, e.g. English “march” [mɐ:tʃ] ↔ Niuean *masi*. Such examples may suggest different adaptation rules operating at different times in the history of English-influenced Niuean.

Part of the explanation for these irregularities may lie in historical morpheme boundaries which may still have some effect on prosody. Four of these forms contain the causative prefix *faka*-, which is used extensively in Niuean grammar (see Sperlich 1997:62-63 and Gould, Massam, and Patchin,. 2009 for analysis of *faka*-). For example, according to Sperlich (1997:63), <fakaaue> 'to thank someone' likely derives historical from the *faka*- and *oue*. Additional potential historical morpheme boundaries within these irregular words are provided in (21), taken from Sperlich (1997) and the POLLEX comparative dictionary of Polynesian languages[18].

(21) Possible historical morphemes within these irregular words

Spelling	Meaning	Potential morphemes	Notes
<fakaalofa>	'to love/hello'	faka + alofa	-
<fakaatukehe>	'to worry'	faka + atu + kehe	Proto-Polynesian: *faka-qatu 'arrange in row or line'
<fakaaue>	'thank you'	faka + oue	-
<fakapaakau>	'to pretend to be helpful'	faka + pa + akau	-
<maataata>	'to be dawn'	ma + ata + ata	Reduplication; Proto-Polynesian: *ma(a)foa(a)t(a)a 'dawn'
<ulaafia>	'to be uncontrollable'	?	Etymology unknown-
<kaiālu>	'to curse someone'	kai + ?	*kai* 'eat', as in 'spirit will eat someone'
<pēa>	'thus, like this'	pē + a	Archaic; Proto-Polynesian: *pee 'be like'

Additionally, the word *maataata* 'to be dawn' is also likely composed historically of ma+ata+ata (exhibiting reduplication), suggesting a historical morpheme boundary.

For the three remaining words with less transparent historical original – *ulaafia*, *kaiālu*, and *pēa* – we sought the modern pronunciation of these words with two fluent Niuean speakers. Our phonetic transcriptions of these words are provided in the table in (22) below.

[18] POLLEX is available at <http://pollex.org.nz/>; see references within Greenhill and Clark (2011).

(22) Pronunciation of irregular words[19]

Spelling	Pronunciation		Pronunciation types	Remains Irregular
	Speaker 1	Speaker 2		
<ulaafia>	[úlaʔafia]~ [ùlaʔafía]	[ula:fía]	Double, Long	Yes/No
<kaiālu>	[kàiaálu]~ [káiaàlu]	[kàiaálu]	Double	No
<pēa>	[pé:a]	[péa]	Long, Short	Yes/No

For the form *ulaafia* spelled with a double vowel, this revealed variation in its phonetic realization. Speaker 1 pronounced the <aa> sequence as a clear double-articulation with a phonetic glottal stop intervocalically, whereas speaker 2 pronounced this with the expected long vowel. Further, the written long vowel <ā> form *kaiālu* was spoken by both speakers as a double vowel with stress on the second half of the sequence. Finally, the written long vowel <ē> of the word *pēa* was pronounced by speaker 1 with a long vowel, remaining irregular, whereas speaker 2 pronounced this as a short vowel rather than a double vowel. These data reveal variation in the pronunciations of these words, some of which align with our predictions. When these historical facts are taken together with the variability of pronunciation of these irregular forms, they support our analysis that the distribution of long and double vowels in Niuean is almost always predictable from the prosodic system.

4. Phonetic study

To support our claim that the distribution of long and double vowels is conditioned by Niuean stress assignment, we completed a short phonetic study targeting short, long, and double vowels in different contexts. Our small study showed that although short vowels are consistently distinguished from long and double vowels by duration, long vowels and double vowels are consistently distinguished from one another by pitch rather than duration. We see this small study as setting the stage to a larger phonetic study to be completed in the future.

Recordings were conducted with one female L1 Niuean speaker in her early thirties[20]. Recordings of the vowel types were produced in complete isolation, in an isolated word, and in a sentential context. Our full set of instructions for our recording is found in the Appendix at the end of this paper. Sample words and context sentences were taken from Sperlich (1997), where available. These sample sentence types were not uniform, and the targeted words were found in a number of sentence locations, adjacent to different types of words[21]. This study presents only measurements of native Niuean words; data on loanwords are not included in this summary.

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[19] Impressionistic secondary stress is indicated by a grave accent ◌̀. In some cases, the leftmost word stress alternated with the rightmost word stress with respect to primary/secondary prominence. Further exploration of this alternative is required, involving full control over morphosyntactic, semantic, and pragmatic variables. For secondary stress, see further section 5.

[20] The speaker for these recordings was born in Niue, but had resided in New Zealand for ten years at the time of the recording. The Niuean speaker had been employed in a radio station in Niue, and was very familiar with a recording studio.

[21] We acknowledge the shortcomings of this methodology. A larger phonetic study would ideally additionally put targeted words in specific carrier sentences. We do not feel, however, that the specific

Individual targeted words containing a long or double vowel type were coded for the following information:

(23) Coding of individual sound files
  a. Word
  b. Vowel: [a], [a:], [aa], [e], [e:], *etc*.
  c. Vowel type: short, long, double
  d. Duration of vowel (in milliseconds)
  e. Context: sound in isolation (P), word in isolation (W), word in declarative sentence (S)
  f. Underlying position(s): monosyllable, ultimate, penultimate, antepenultimate, pre-antepenultimate
  g. Surface syllable position(s): monosyllable, ultimate, penultimate, antepenultimate, pre-antepenultimate
  h. CV template of word: CV, CV:, CVVCV, etc.

Syllables were coded for both their underlying vowel position (as proposed here, pre-syllable fusion), and their surface syllable position. Short vowels occur in one slot at both the surface and underlying level, long vowels occur in two underlying positions and one surface position, and double vowels occur in two syllable positions at both levels. Further, for words involving double and long vowels, we also coded for pitch information, including maximum pitch, minimum pitch, location of maximum pitch, and pitch change over the vowel sequence.

The table in (24) provides measurements of vowel types when pronounced in complete isolation, i.e. not within any word. The vowels represent her attempts to produce the vowel types in complete isolation before she focussed on the pronunciation of words containing these vowels. We measured the duration of 22 isolated short vowel tokens, 19 isolated long vowel tokens, and 22 isolated double vowel tokens, totalling 63 tokens. We use these measurements as a crude basis of comparison before considering vowel types used in actual words and sentences[22].

environments which these words appeared in had an effect on the realization of their vowel type. In ex. (2) above, we illustrated variation in the realization of long and double vowels, based on how multiple grammatical words formed a single phonological word. In the sentences we used with double vowels, the surrounding environment did not appear to affect its realization as a double vowel. For example, Task 1 in Appendix 1 targeted the pronunciation of the word *iihi* ‘to split lengthwise’ using the sentence *Kua iihi e ia e fua meleni ke kai* ‘He split the water melon to eat’. Here, even though *iihi* follows the grammatical word *e*, there is an audible break between *iihi* and *e* in our consultant’s pronunciation, showing they do not form a single phonological word.

[22] Our full set of measurements and statistics are available upon request.

(24) Table: Mean duration of short, long, and double vowels produced in complete isolation, in msec. (N = 63)

Short				Long				Double			
Vowel	Tokens	Duration (msec.)		Vowel	Tokens	Duration (msec.)		Vowel	Tokens	Duration (msec.)	
		Mean	SD			Mean	SD			Mean	SD
a	8	210.28	29.77	a:	6	337.01	12.62	aa	6	398.85	34.74
e	2	167.52	20.29	e:	5	380.23	52.29	ee	2	375.14	14.26
i	4	271.83	27.22	i:	2	351.50	18.89	ii	4	432.08	17.81
o	4	244.88	38.33	o:	4	368.76	36.60	oo	6	411.51	39.16
u	4	236.06	22.28	u:	2	353.28	7.72	uu	4	395.53	23.02
Total	22	228.56	40.02	Total	19	358.31	34.86	Total	22	405.59	32.36

From this table, we see that when vowel types are pronounced in isolation, short vowels are on average shorter in duration than both long and double vowels. Vowel duration ratios are provided in (25), showing long vowels to be about 1.5 times short vowels, and double vowels 1.75 times short vowels.

(25) Vowel duration ratios of duration means – Vowels in isolation
Short : Long : Double
228.56 : 358.31 : 405.59
1 : 1.56 : 1.77

Having this ratio as a basis of comparison, we measured the durations of short, long, and double vowels in different word and sentence context in native Niuean words, totalling 320 tokens. We present a condensed form of this table in (26) below constituting 278 tokens, which shows the duration measurements of vowel types in specific targeted environments. This table presents measurements of short vowels, long vowels, and double vowels. In this table, the short vowels were categorized by which underlying context they occurred in: (1) in monosyllable grammatical words (i.e. *ko*), (2) in ultimate syllable position (occurring after primary stress), and (3) in penultimate syllable position (bearing primary stress). Long vowels were categorized by two types: (1) in ultimate surface syllable position (bearing primary stress), and (2) in non-ultimate surface syllable position (before primary stress). Double vowels have only one main type: those that appear in antepenultimate-penultimate position with primary stress (e.g. C$\underline{V_i\acute{V}_i}$CV). In this table, the targeted part of the word whose duration we measured is underlined.

(26) Vowel types in isolation (W) vs. in sentences (S) (N = 278)

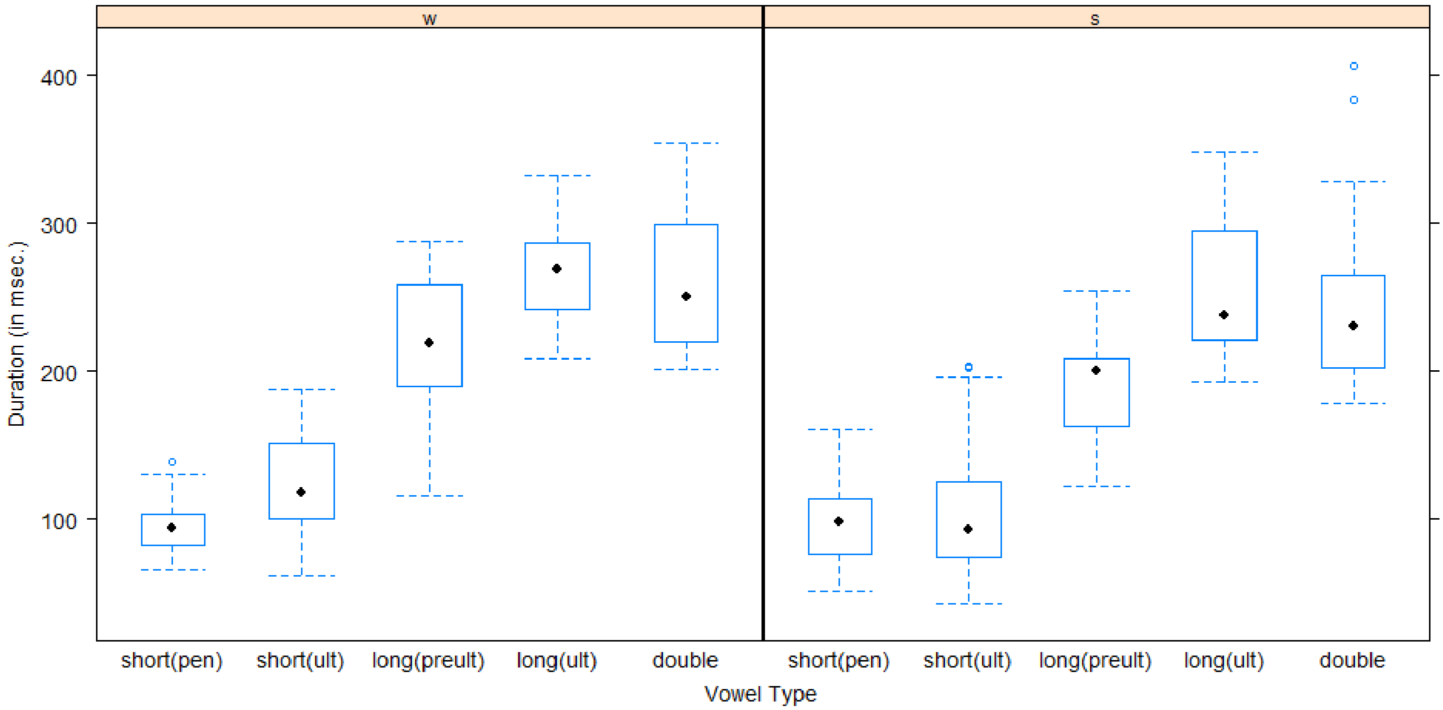
Vowel type	Underlying position	Syllable	Template	W			S		
				N	Dur. (msec.)		N	Dur. (msec.)	
					Mean	SD		Mean	SD
Short /V/ [V] (N = 174)	Monosyllabic	[σ]	CV	16	236.68	21.61	16	90.26	35.19
	Ultimate	[…σ́σ]	CV́CV CVCV́CV CVV́CV CV:CV́CV *etc.*	45	123.58	31.69	52	104.51	44.85
	Penult.	[…σ́σ]	CV́CV V́CV CVCV́CV CV:CV́CV *etc.*	23	94.64	18.80	22	98.36	27.58
Long /VV/ [V:] (N = 60)	Ultimate	[…σ́:]	CV́: CVCV́: CV:CV́:	16	267.65	33.42	8	256.32	54.31
	Pre-ultimate	[…σ:σ́:] […σ:σ́σ]	CV:CV́: CV:CV́CV *etc.*	15	218.83	50.40	21	188.60	35.35
Double /VV/ [VV] (N = 44)	Ante.–Penult.	$[\ldots\sigma_i\acute{\sigma}_i\sigma]$	CVV́CV VV́CV CVCVVCVV́CV	18	258.11	45.15	26	243.14	57.36

A number of things can be observed from this table. As one might expect, the average duration of vowels pronounced in isolation is longer than vowels spoken within sentences, consistent for short, long, and double vowels. Further, the difference between short vowels vs. other vowel types is clear. Short vowels in ultimate and penultimate position range from 94.64 to 123.58 msec. on average, whereas the duration is much greater for long vowels in ultimate position (256.32-267.65), long vowels in non-ultimate position (188.60-218.83), and double vowels (243.14-258.11). Further, unlike compared to short vowels, the duration differences between long and double vowels overlaps significantly. Using box and whiskers plots, we can compare the durations and duration ranges of vowels in syllables which have a suitable number of tokens, shown in (27)[23]. The dot within the box indicates the median value of the vowel type for that context. The box provides the interquartile range (one quarter of data above and below the median, i.e. 50 percent of total data), and the dashed lines

[23] These plots were made with statistical computing software R (http://www.r-project.org/). See Baayen (2008:30-31,79-81) for additional information on these plots in R.

(the whiskers) indicate the fuller range of the data, 1.5 times the interquartile range; points falling outside the whiskers are outliers.

(27) Vowel type duration in isolated words (W) and declarative sentences (S)



These plots show that the interquartile range for long and double vowels is roughly between 200-300 msec. in isolated words, and slightly less in sentences. The interquartile regions of short vowels is consistently outside the interquartile regions of long and double vowels, suggesting that these short vowels can be reliably differentiated from long and double vowels through duration. In contrast, there is considerable overlap of the interquartile regions of double vowels and long vowels, suggesting duration as a less reliable cue.

To further compare long and double vowel durations, we ran statistical tests targeting whether the duration differences of the long vs. double vowel types summarized in table (26) above were statistically significant. Table (28) provides the results from a statistical t-test (assuming a normal distribution), and table (29) provides the results from a Wilcoxon statistical test, both of which compared these vowel type durations[24].

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[24] The Wilcoxon test is a non-parametric test used for datasets which do not follow a normal distribution, unlike the t-test used when one can assume normal distribution (see Baayen 2008:76-77). We provide a Wilcoxon test here as well as a t-test because some of our data for certain vowel types did not follow a normal distribution, or there were few too tokens to assume a normal distribution. Log-transforming the duration data improved normal distribution only slightly. Of the 6 data sets used in comparing vowel types in different contexts, only one had fewer than 10 tokens (long vowels in ultimate position in sentence contexts).

(28) T-tests – Comparing duration of long vs. double vowels

Vowel types compared	Context	
	W	S
Double vs. Long (ultimate)	p = .4858 Not significant	p = .5643 Not significant
Double vs. Long (pre-ultimate)	p = .02672 Significant	p = .0002507 Significant
Long (ultimate) vs. Long (pre-ultimate)	p = .004247 Significant	p = .00916 Significant

(29) Wilcoxon tests – Comparing duration of long vs. double vowels

Vowel types compared	Context	
	W	S
Double vs. Long (ultimate)	p = .266, W = 111 Not significant	p = .5104, W = 87 Not significant
Double vs. Long (pre-ultimate)	p = .052, W = 81 Not significant	p = .0003, W = 111 Significant
Long (ultimate) vs. Long (pre-ultimate)	p = .0055, W = 51 Significant	p = .0008, W = 19 Significant

These tables reveal that in both isolated words and in sentence contexts, durations of long vowels in ultimate position and double vowels were not statistically significantly different ($p > .05$). In other words, it cannot be conclusively established that long vowels and double vowels converge on different targeted durations when the vowels bear primary stress, and any duration differences between them could be due to chance. These tests also revealed that although durations of double vowels and long vowels in a pre-ultimate position were not significantly different in isolated words under a Wilcoxon test, the durations were significant in sentence context under this test, and significant for the t-test in both contexts. Finally, they also revealed that durations of long vowels in different syllable types were significantly different in both contexts. These results require additional study with a greater number of tokens for each category in varied contexts, though stand at the present as in line with our analysis[25].

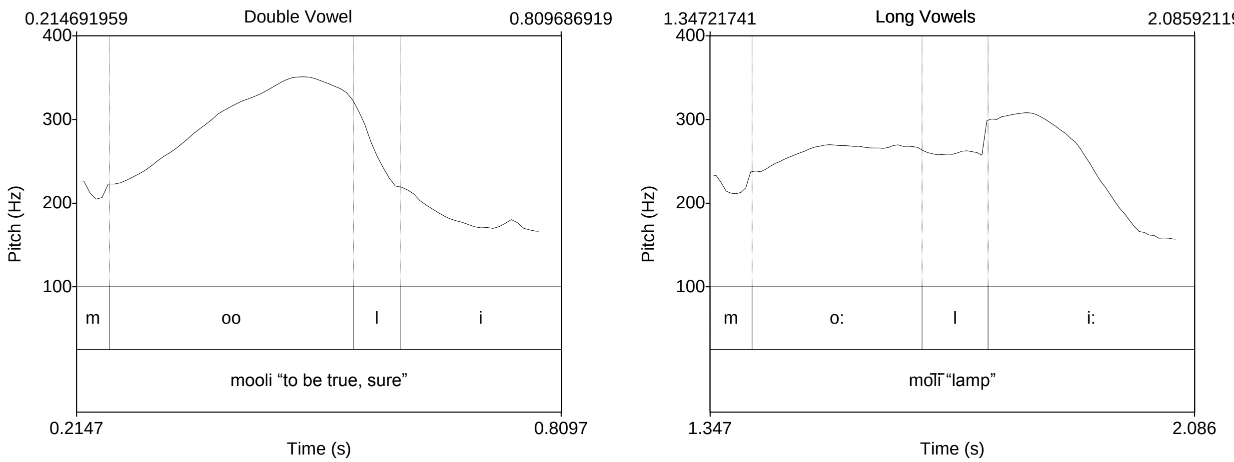
Under the phonological analysis put forward here, it is the location of stress which conditions the distribution of long and double vowels. Therefore, if long and double vowels are primarily distinguished by stress, and understand that stress in Niuean is correlated with increased pitch on the stressed vowel, then we might expect long and double vowels to be distinct in terms of how pitch is realized on these vowel types. Our phonetic study confirms this, revealing that a more reliable distinguishing cue between long and double vowels appears to be pitch height over the vowel sequence.

The differences in pitch over the different vowel types can be observed in the pair *mooli* ‘to be true, sure’ with stress pattern [moóli], and *mōlī* ‘lamp’ with stress pattern

[25] Explaining why long vowels in different word positions have significantly different durations is outside of the scope of this paper, and can be tied to the fact that primary stress falls on double vowels and long (ultimate) vowels, but not on other positions. What is important is that overall these statistics provide evidence that duration is not a reliable cue for distinguishing double and long vowels as a whole.

[mo:lí:]. Pitch tracks of this pair are shown in (30). The left diagram captures the pitch changes with the double vowel [oo], showing a significant and steady rise in pitch throughout the duration of the vowel type, peaking in pitch towards the end portion. This pitch peak corresponds to the primary stress falling on the second half of this vowel sequence. In contrast, the right diagram shows long vowels [o:] and [i:], showing distinct pitch patterns. The pre-ultimate long vowel [o:] shows steady pitch throughout its duration, with no clear rises or falls, or clear pitch height. In contrast, the ultimate long vowel [i:] shows a pitch peak towards the initial part of the vowel, and steadily falling off towards the lower parts of the speaker's pitch range. The pitch peak here corresponds to primary stress falling on the first half of this vowel.

(30) Pitch tracks of double vs. long vowels – *mooli* vs. *mōlī*



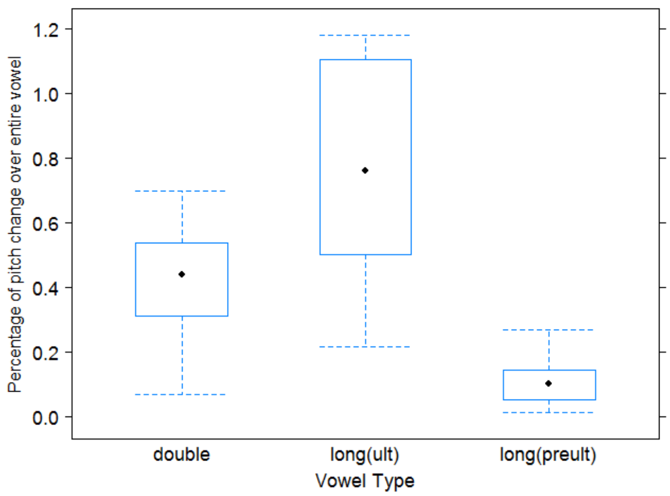
We find that these types of pitch patterns hold across a sample of 104 word tokens of long and double vowels, for both isolated words and words in sentence contexts. We coded the relevant vowels in these data for (1) duration, (2) minimum pitch, (3) maximum pitch, (4) percentage of pitch change from min to max, (5) location of max pitch, and (6) percentage of the vowel completion at the maximum pitch mark. In total, we measured 44 double vowels, 24 long vowels in ultimate position, and 36 long vowels in pre-ultimate position. The relevant findings are summarized in (31), providing the mean values of the percentage of pitch change and the percentage of vowel completion at the maximum pitch mark.

(31) Pitch statistics

Vowel Type	N	Percentage of pitch change		Percentage of vowel completion at max pitch	
		Mean	SD	Mean	SD
Double	44	40.95%	16.99%	89.01%	6.82%
Long (ult)	24	78.06%	31.97%	33.54%	23.25%
Long (pre-ult)	36	10.74%	6.15%	49.59%	37.91%

The statistics under the “Percentage of pitch change” column show that on average, the pitch within long vowels in ultimate position changes the most, with the maximum pitch being 78 percent greater than the minimum pitch. This is associated with a large falling pitch as shown in the pitch track in (30) for [lí:] in <mōlī>. In contrast, double vowels change by approximately 41 percent on average, and long vowels in pre-ultimate position change the least, approximately 11 percent on average. A box and whiskers plot is provided in (32), illustrating the medians and interquartile ranges of pitch change percentage, visualizing the clear differences between these vowel types[26].

(32) Plot of percentage of pitch change over different vowel types

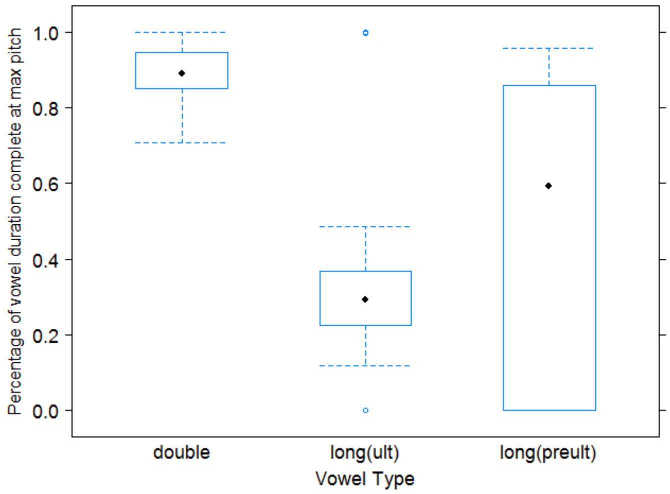


Further, the statistics in the table in (31) under the column “Percentage of vowel completion at max pitch” also reveals key differences between these vowel types. This column is associated with where maximum pitch is reached within a vowel. In double vowels, maximum pitch is consistently reached towards the end of the vowel, after approximately 89 percent of the vowel is complete on average. In contrast, with long vowels in ultimate position bearing primary stress, maximum pitch is reached towards the beginning of the vowel, after approximately 34 percent of the vowel is complete on average.

Moreover, although table (31) shows that long vowels in pre-ultimate surface syllable position have an average peak at about 50 percent competition, no reliable max pitch target point could be determined, reflected in the high standard derivation. This is illustrated in the plot in (33). Here, the interquartile range of double vowels and long vowels in ultimate position is relatively tight, showing greater convergence on a single target, towards the end and beginning of the vowel type respectively. This is in contrast to the interquartile range of long vowels in pre-ultimate position, which encompasses nearly the entire potential range, suggesting no convergence on a specific target for maximum pitch location. The issue of (secondary) stress at this location is discussed in the section below.

[26] Unlike the duration plots, we did not split between contexts (isolated words vs. words in sentences) with these data, as there did not appear to be major differences between the two.

(33) Plot of percentage of vowel completion at max pitch



We interpret these pitch peaks as the phonetic correlates of stress, supporting our analysis that long and double vowels are surface variants of underlying identical short vowel sequences /V_iV_i/, and that speakers may be attending primarily to pitch rather than duration when they distinguish long from double vowels. Garellek and White (2012) show that both factors are important in Tongan vowels with primary stress cued by differences in pitch and duration with pitch being the best indicator of primary stress. They also point to additional factors that should be examined such as intensity, F1, and voice quality, which should also be examined for Niuean.

5. An outstanding issue: Secondary stress

In this paper, we have limited our discussion to primary stress. In previous studies on Niuean and Polynesian, secondary stress has also been discussed. Sperlich (1997:10) notes that Niuean secondary stress occurs on short vowels which occur in surface penultimate syllable position preceding a long vowel, and on long vowels in any position other than the surface ultimate syllable position. Examples extrapolated from Sperlich are in (34).

(34) Secondary stress examples from Sperlich (1997:10)

a.	molī ‘lamp’	b.	kālagi ‘a bird’
	[mòlí:]		[kà:láŋi]

Under Sperlich’s statement of Niuean secondary stress, stress clash is allowed between stressed vowels, and not all stressed vowels must be in a penultimate position within a stress group[27].

Further, secondary stress statements have also been made for Tongan, although with different generalizations. Taumoefolau (2002:344) claims that “words longer than single stress groups are usually compounds, derived words, and reduplications which

[27] This analysis of secondary stress in Sperlich should be evaluated against the literature on pre-accentual lengthening, e.g. Dasher and Bolinger (1982). For purposes of space, we do not further comment on this. We thank Jason Brown for bringing this to our attention.

are organised into combinations of twos and threes," and that in such words "the stress in the final stress group becomes the primary stress while the stress in every other stress group is of secondary status" (underlining ours). The organization into these 2- and 3-unit stress groups is variable. For example, the sentence '*o ka ke ka 'alu leva pea ke ui mai* 'when you leave, call me' can be pronounced as ['ó-ka/ké-ka/'á-lu/lé-va/pe=á-ke/ú-i/má-i] or as ['o=ká-ke/ka='á-lu/lé-va/pé-a/ke=ú-i/má-i] with a different organization. Further, in a later study, Garellek and White (2012) show that primary stress and secondary stress are different phonetically, as well as being different where they occur in a word. They show that Tongan vowels with secondary stress on vowels are reliably cued only by pitch.

This conception of secondary stress reflects a position widely held in the work of Schütz that secondary stress in Polynesian/Fijian cannot be predicted merely by counting moras/syllables from either primary stress location or from the right edge of the word. For example, Schütz (1999) shows that Fijian has two basic stress group structures, bimoraic and trimoraic, within which the "pitch peak" falls on the penultimate mora. The type of stress groups a word shows depends on lexical and morphosyntactic facts, and cannot be predicted phonologically. For example, for 5-syllable words, Schütz (1999:144) shows both 3σ-2σ organization such as (i.ka.wa).(ka.wa) 'bridge', as well as 2σ-3σ organization such as (ba.ti).(ni.sa.vu) 'cliff'[28]. We therefore see that compared to primary stress, secondary stress presents additional complications in Polynesian/Fijian with respect to both (1) their location within a word, and (2) determining their phonetic correlates.

Although secondary stress is clearly relevant to our analysis, we do not incorporate it within our analysis for the following reasons. First, the phonetic and phonological differences between secondary and primary stress warrant secondary stress being a study in its own right, outside of the scope of this present paper. Second, we conducted a follow-up study to our original phonetic study with three different Niuean speakers, targeting secondary stress. We found that none of the three speakers had clear, unambiguous secondary stress for all words we elicited, both impressionistically and when we measured instrumentally. For example, speaker 1 (the oldest speaker) produced secondary stress on most of her pronunciations, though not all, e.g. *amanaki* 'to be prepared/ready' [amanáki]. In contrast, speakers 2 and 3 produced an opposite trend, having no clear secondary stress with most words. No clear patterns emerged as to which words have secondary stress and which did not.

In addition, the location of secondary stress was far from consistent in our data, both within and across speakers. No speaker had a clear intuition where secondary stress occurred in a word, unlike primary stress. Finally, there were a number of instances in which there was high pitch on one to two syllables preceding the primary stressed syllable. For example, the place name *Oneonepata* [oneónépâta] (question and declarative sentence), *tāfoleke* 'to hit, knock' [tá:fóléke], among many others. Part of the difficulty here is distinguishing between anticipatory pitch increases which occur on syllables preceding the primary stress, versus pitch increase due to true secondary stress. Such ambiguity has likely contributed to the various previous statements on secondary stress, e.g. those noted from Sperlich and Taumoefolau above.

[28] An anonymous reviewer points out that secondary stress may be sensitive to an initial dactyl effect.

Finally, we feel that any methodology devised to determine secondary stress patterns must be constructed with particular care so as to not falsely impose prosodic categories on the target language from the researcher's first language, so called "stress ghosting" (see Tabain, Fletcher, and Butcher, 2014 for a recent study of this issue in the Australian language Pitjantjatjara). We therefore conclude then that further studies of Niuean secondary stress are needed before anything definitive can be said, targeting the location of secondary stress and its phonetic correlates. What is important to take away here is that the distribution of long and double vowels appears to remain the same whether or not secondary stress unambiguously surfaces in a specific word or token.

6. Concluding remarks

This paper has put forward two sources of evidence for analysing two vowel types in Niuean - long vowels and double vowels - as contextual variants of an underlying sequence of two identical adjacent short vowels /V_iV_i/: They are dictionary evidence from the main entries of *Sperlich's Tohi vagahau Niue – Niuean language dictionary* and phonetic recordings of a small number of words from the dictionary. We have argued that the distribution of long and double vowels is conditioned by the prosodic stress algorithm of the language: double vowels surface when primary stress falls on the second vowel of an identical vowel-vowel sequence, whereas long vowels surface elsewhere. We have supported our analysis through a comprehensive dictionary survey which revealed that the vast majority of instances of long or double vowels are predictable, for both native words and non-native loanwords. Further, our small phonetic study revealed that although short vowels can be consistently distinguished from long and double vowels by duration, in contrast, long vowels and double vowels are consistently distinguished from one another by pitch rather than duration, a main phonetic correlate of stress.

Under our analysis, stress is not "attracted" to long vowels *per se*, but rather conditions their occurrence in the first place. The few exceptions we deduced from our survey can be explained diachronically, by appealing to historical internal morpheme markers and their effects on prosodic licensing. In addition, in the elicitation data we gathered from speakers, our observations reveal minor variation in primary stress, and much more significant variation in secondary stress. This suggests that the Niuean stress algorithm may be undergoing synchronic changes, which may have important repercussions for teaching the Niuean language. A weaker stress algorithm may add an additional challenge to Niuean language pedagogy, as variation of stress assignment among speakers may destabilize community norms and result in greater learner and speaker uncertainty of word and sentence pronunciations.

Given these observations on stress, we strongly suggest larger studies which expand on our present analysis and the framework we have established using CV templates. Through such studies, we will be able to systematically establish stress patterns as they exist in both conservative and modern Niuean speech for both primary and secondary stress (if possible), and be able to control for the full set of speaker variables (place of residence, proficiency, among others).

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Appendix: Instructions from our Niuean recordings

Task 1: Vowel types and words in isolation, and in sentences

I. SOUNDS

Instructions: Read from left to right

(a) Pronounce the sound.
(b) Repeat the sound.
(c) Pronounce the word containing the sound.
(d) Read the sentence.
(e) Repeat the sentence.
(f) Move on to the next sound.

	SOUND	WORD	SENTENCE
1.	[a]	afua	Ko e aho afua anei.
	[ā]	āfou	Ne tokiofa e ia haana a āfou.
	[aa]	aafu	Aafu ai pihia e aho nei.
2.	[i]	ihu	Kua toto e ihu haana.
	[ii]	iihi	Kua iihi e ia e fua meleni ke kai.
3.	[o]	ota	Mitaki lahi e ulihega ke ota.
	[ō]	ōtai	Mitaki lahi e ōtai tī he inu.
	[oo]	ooki	Ooki fakakū a ia he lalo mago.
4.	[u]	ufi	ufi kakokakō
	[uu]	uufi	Uufi e tau mena kai!

II. SOUNDS

Instructions: Same as in (I)

(a) Pronounce the sound.
(b) Repeat the sound.
(c) Pronounce the word containing the sound.
(d) Read the sentence.
(e) Repeat the sentence.
(f) Move on to the next sound.

	SOUND	WORD	SENTENCE
1.	[a]	takape	Ko ia ko e takape.
	[ā]	tākai	Kua tākai aki e loloniu e tama mukemuke.
	[aa]	taaki	Kua taaki e au e huli futi.
2.	[e]	peka	Peka e uga.
	[ē]	pēkau	Ko e pēkau moa.
	[ee]	peehi	Ua peehi mai ne mamafa.

	[ē]	pēhia	Ku pēhia e kumā he puhala tū.*[29]

III. SOUNDS

Instructions: Same as in (I)

(a) Pronounce the sound.
(b) Repeat the sound.
(c) Pronounce the word containing the sound.
(d) Read the sentence.
(e) Repeat the sentence.
(f) Move on to the next sound.

	SOUND	WORD	SENTENCE
1.	[i]	kite	Kua kite nakai
	[ī]	kītā	Pelē kītā a Moka*
	[ii]	iite	Kua iite haana a tau nifo
2.	[o]	koki	Kua koki a ia ke kitia atu taha faahi he kaupā
	[ō]	kōkio	Kua kōkio e manu*
	[oo]	hooku	Ko e hooku kato a ē
	[oo]	hooto	Fakaleo mai lā e kupu ‘hooto’*
3.	[u]	tutu	Ne tō a ia he tutu
	[ū]	tūtū	Ne tūtū e lautolu e puaka
	[uu]	tuula	Kua gahua fakamalolō a ia ke tū he tuula

Task 2: Word pairs in isolation

Instructions: Read from left to right

(a) Say the first word [pause], then say the second word.
(b) Ask in the Niuean language: ‘*which word is it*?’ [*ko e kupu f*ē *a* ē?]
(c) Say the underlined word [e.g. hapā]
(d) Repeat the underlined word.
(e) Go to the next word pair.

1.	kapa	<u>kapā</u>
2.	<u>pake</u>	pakē
3.	puhi	<u>puhī</u>
4.	<u>koko</u>	kokō
5.	<u>paku</u>	pakū
6.	mooli	<u>mōlī</u>

Task 3: Monosyllabic grammatical words in isolation and in context

Instructions:

[29] As there was no contextualised example for this word, our participant constructed her own in some instances.. All instances are marked with an asterisk.

(a) Pronounce the grammatical word. Pause, repeat.
(b) Read the sentence containing the grammatical word. Pause, repeat.
(c) Go to the next word.

	WORD	SENTENCE
1.	ha	Ko ia ha ne gahua ka e okioki a mautolu.
2.	ka	Fia manako au ke kai taha mena ka kua makona tuai.
3.	he	Kua kitia he tagata e kalahimu.
4.	ke	Talaage ki a ia ke hau.
5.	i	Kua hiki e ia e vaka haana i Nukututaha.
6.	ti	Ka kitia e koe e uga ti tapaki.
7.	ko	Ko e fuakau e akoako.
8.	to	To ō a tautolu mo ia.

Task 4: More natural speech involving /a/ and /u/

Instructions:
(a) Read the word.
(b) Put the word in a sentence.
(c) Repeat the word and the sentence.

WORD	SENTENCE
lā	Ko e lā e akau popo.
laā	Laā ha ia he aho nei.
halā	Tohi fēfē e kupu halā.
hala	Ha fē e hala? Fano hala ko.
haau	Ko e haau nakai e pepa e.
āfine	Ko e āfine Avatele.
fakaatāaga	Fai fakaatāanga nakai a koe ke hu mai ki fale.
fakaataaga	Ai fai fakaataaga a ia.
femaāki	Kua femaāki a lautolu.
uufi	Uufi e kai?
uū	Ko e higoa e kupu uū?
huhu	Inu huhu e tama muke.
hūhū	Ko e higoa e hūhū haau?