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Acoustic evidence for right-edge prominence in Nafsan[a)]

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Oceanic languages are often described as preferring primary stress on penultimate syllables, but detailed surveys show that many different types of prominence patterns have been reported across and within Oceanic language families. In some cases, these interact with segmental and phonotactic factors, such as syllable weight. The range of Oceanic prominence patterns is exemplified across Vanuatu, a linguistically diverse archipelago with over 130 languages. However, both impressionistic and instrumentally-based descriptions of prosodic patterns and their correlates are limited for languages of this region. This paper investigates prominence in Nafsan, an Oceanic language of Vanuatu for which previous observations of prominence differ. Acoustic and durational results for disyllabic and trisyllabic Nafsan words show a clear pattern of higher fundamental frequency values in final syllables, regardless of vowel length, pointing towards a preference for prominence at the right edge of words. Short vowels also show centralisation in penultimate syllables, providing supporting evidence for right-edge prominence and informing the understanding of vowel deletion processes in Nafsan.

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I. INTRODUCTION

This paper investigates prominence in Nafsan (South Efate), a Southern Oceanic language spoken by an estimated 6,000 people in three villages (Erakor, Eratap and Pango) on the island of Efate in Vanuatu. The phonology of Nafsan has been discussed in comparative and descriptive work (Clark, 1985; Lynch, 2000c; Thieberger, 2006), but for some aspects of the segmental and prosodic system there have been different views, and some challenges to identifying clear patterns. In particular, until very recently there have been open questions relating to whether there is a vowel length distinction in the language, why some vowels undergo deletion, and what patterns of word- and phrase-level prosodic prominence are used. There are also indications that there are crucial interactions between vowel distinctions, vowel deletion, and prominence patterns, and that these therefore need to be considered together in order to adequately describe the sound system of Nafsan. For example, it has been proposed that the major factors influencing vowel deletion in Nafsan are phonemic vowel length and proximity to an accented syllable, based on impressions that final syllables have accentual prominence (Billington *et al.*, forthcoming, 2019), but these impressions differ from some previous observations and have not been verified empirically. The present study is part of a wider project using instrumental phonetic approaches to investigate various aspects of Nafsan phonology. Here, we examine prominence patterns observable at the lexical level in Nafsan, focusing on whether there is evidence that syllables are more prominent when they occur at the right edge. We identify the acoustic cues associated with prominence patterns, and discuss how the findings relating to prominence inform other aspects of the Nafsan sound system.

A. Prominence in Oceanic languages

For Oceanic languages, and Austronesian languages more generally, comprehensive descriptions of prosodic patterns (based on auditory impressions or instrumental investigations) are scarce (Himmelmann and Kaufman, to appear, 2019). At the lexical level, Oceanic languages are often described as preferring primary stress on penultimate syllables (Lynch *et al.*, 2002; Ross, 1998). However, crosslinguistic examinations suggest that this tendency may not be as widespread as previously thought, with a range of patterns observed across Oceanic languages (Lynch, 2000b), including among the more than 130 Southern Oceanic languages of Vanuatu.[1] While some languages of Vanuatu are described as having regular penultimate stress, such as Erromangan (Crowley, 1998, p. 17), many are described as having a weight-sensitive system whereby stress is penultimate unless the final syllable contains a coda consonant, as in Tamambo (Riehl and Jauncey, 2005, p. 258), and/or a long vowel or diphthong, as in Naman (Crowley, 2006, p. 39), in which case stress is final. Some languages are reported to have reliably final stress, such as Vurës (Malau, 2016, p. 38), while others may only have final stress if a word-final vowel has been deleted, as in Lelepa (Lacrampe, 2014). Very occasionally, antepenultimate stress is suggested, as in Nguna (Schütz, 1969, p. 11), and in other cases stress may be lexically contrastive, as in Paamese (Crowley, 1982, p. 19). Some grammatical descriptions note prominence patterns which suggest phrasal accent rather than lexical stress, for example in Nahavaq (Dimock, 2009, pp. 46–55), Daakaka (von Prince, 2015, pp. 34–40), and Mwotlap (François, 2001, p. 81). Given the different hypotheses regarding the status of stress in these languages, we use the more general term prominence in this paper.

There is increasing interest in developing instrumentally-based descriptions of word-, phrase- and utterance-level prosodic patterns in Oceanic languages, as can be seen in recent research on Central Pacific languages of Polynesia such as Samoan (Calhoun, 2015, 2017; Yu and Stabler, 2017; Zuraw *et al.*, 2014), Māori (Mixdorff *et al.*, 2018; Thompson *et al.*, 2011), Tongan (Garellek and White, 2015; Kuo and Vicenik, 2012), and Niuean (Clemens, 2014, to appear, 2019). There are also some prosodic analyses of languages from other Oceanic groups, such as the Northwest Solomonic language Torau, of Papua New Guinea (Jepson, 2014), the Southeast Solomonic language Gela (Simard and Wegener, 2017), from the Solomon Islands, and the Southern Oceanic language Drehu, of New Caledonia (Torres *et al.*, 2018). For the languages of Vanuatu, there are some phonetically-based explorations of prosodic patterns, such as for Nahavaq (Dimock, 2009, pp. 46–55), Daakaka (von Prince, 2015, pp. 34–40) and Mavea (Guérin, 2019), but for most languages, prosodic descriptions are limited to impressionistic comments relating to word stress or lexical prominence, with little information regarding how these might be realised. Existing descriptions also have limited scope for examining how prominence phenomena interact with other aspects of a language's phonology. This is of particular interest in the Vanuatu context, given that beyond the variety of attested prominence patterns, the languages of Vanuatu also show striking diversity in their segmental inventories and phonotactic structures.

Crosslinguistically, a range of acoustic and durational cues correlate with lexical stress, though much of the instrumental phonetic research on stress has focused on languages with similar genetic and typological profiles. Overviews of production patterns in Germanic languages such as English and Dutch, and to a lesser extent languages from elsewhere in Europe, show that correlates of stress include higher fundamental frequency, increased loudness/intensity, increased vowel duration, and more peripheral vowel quality for stressed compared to unstressed syllables (Lehiste, 1970; van Heuven, 2019; van Heuven and Sluijter, 1996; van Heuven and Turk, to appear, 2019). In a survey of acoustic correlates of stress in 75 languages from a range of language families around the world, Gordon and Roettger (2017) find that duration is most widely attested as a primary correlate. These various correlates are also drawn on as auditory cues, for example as seen in in perceptual studies undertaken with speakers of Germanic languages (Cutler, 2005; van Heuven, 2019). The particular cue or combination of cues associated with lexical stress is language-specific, and may depend to some extent on other language-specific phonological properties. Some comparisons across languages suggest that cues to stress may be more robust and consistent in languages for which stress patterns are lexically contrastive, and thereby not predictable, compared to languages with fixed lexical stress patterns, for example as noted by Dogil and Williams (1999) with reference to data for Lithuanian, Polish, German and Spanish and by Vogel *et al.* (2016) with reference to data for Hungarian, Turkish, Greek and Spanish. It has also been argued that for languages in which a suprasegmental property is used contrastively, for example where duration signals phonemic vowel length, this suprasegmental property will not be used as a primary perceptual cue to lexical stress (Berinstein, 1979).

This idea has been interpreted as a prediction relating to patterns of production as well as perception. Although an overview of reported correlates of lexical stress in descriptions of 140 languages finds limited crosslinguistic evidence for such a relationship (Lunden *et al.*, 2017), there are individual languages for which phonetic data suggests this may be relevant, for example Hungarian, which has a vowel length contrast and for which duration is not a correlate of lexical stress (Vogel *et al.*, 2016). Other types of language-specific restrictions on the ways suprasegmental cues can be combined have also been found, for example in the co-occurrence restrictions between tones and vowels in Maastricht Limburgish (Gussenhoven, 2012). Phonotactic factors may also be relevant to both the assignment and realisation of lexical stress; syllable weight plays a role in determining stress location in many languages around the world (Goedemans, 2010), and it has been argued that in such languages, syllables with long vowels or codas are phonetically well-suited to bearing lexical stress due to not just the additional segmental material in a syllable rhyme but the distinctiveness of the overall energy profile of these syllables (Gordon, 2002).

In the Asia-Pacific region, phonetic investigations of lexical stress in Austronesian languages point towards main correlates such as increased fundamental frequency and intensity for Besemah Malay (McDonnell, 2016), increased duration, fundamental frequency movement, vowel quality differences and spectral tilt for Papuan Malay (Kaland, 2019), and increased fundamental frequency and duration for primary stress in Tongan, together with other intensity and spectral differences (Garellek and White, 2015). Among descriptions of the languages of Vanuatu, impressionistic correlates of stress reported in the literature include duration in Tamambo (Riehl and Jauncey, 2005, p. 258), loudness, duration, and vowel quality in Sakao (Guy, 1974, pp. 12-17), duration, pitch and intensity in Lelepa (Lacrampe, 2014, p. 58), intensity and duration in Maskelynes (Healey, 2013, p. 32), and loudness and pitch in Anejom̃ (Lynch, 2000a, p. 24). Anejom̃ is suggested to be an example of a language which has a phonemic length distinction in the vowel system and does not use duration as a cue to stress (Lunden *et al.*, 2017, p. 567). For Lelepa, which has a length contrast for some vowel qualities, exploratory duration measurements indicate that increased vowel duration may correlate with stress, but most noticeably among short vowels (Lacrampe, 2014, pp. 38-41).

B. The sound system of Nafsan

The consonant inventory of Nafsan includes a contrast at four places of articulation for stops /k͡p p t k/ and nasals /ŋ͡m m n ŋ/, and two fricatives /f/ and /s/. There is no voicing distinction among the obstruents. Sonorants include a trill /r/, prenasalised trill /n$^{\text{d}}$r/, lateral /l/, and glides /w/ and /j/ (Thieberger, 2006, p. 46). There is a contrast between vowels of five qualities (Thieberger, 2006, p. 54). The possibility of a length distinction has been mentioned in passing in previous historical-comparative work (Clark, 1985; Lynch, 2000c), but long vowels do not feature in major descriptive work on the language (Thieberger, 2006), nor in other materials published in or about the language apart from the occasional occurrence of orthographic representations with doubled vowels (e.g. Tryon (1976)). However, through recent dictionary workshops and collaborative work with community members (e.g. Krajinović *et al.* (2019)), analyses of archival wordlist data (Billington *et al.*, forthcoming, 2019), and targeted investigations of monosyllabic words using new acoustic phonetic data

(Billington *et al.*, submitted), there is now evidence for a monophthong inventory comprising /i, iː, e, eː, a, aː, o, oː, u, uː/. Each of the five vowel qualities may occur either phonemically short or long, in various syllable types. At least in CVC syllables, long vowels are close to twice as long as short vowels, and the duration difference between long and short vowels is approximately the same across all vowel qualities. There are also indications that long vowels are slightly but not substantially more peripheral than corresponding short vowels in the acoustic space.

Nafsan phonotactic patterns are notably complex compared to patterns for languages spoken further to the north in Vanuatu, and compared to the typological preference for CV syllables among Oceanic languages (Lynch, 2000c; Lynch *et al.*, 2002). Complex codas do not occur, but the language exhibits a range of heterorganic consonant clusters in syllable onsets, with various possible sonority profiles (Thieberger, 2006). There is a relationship between the occurrence of these clusters and a vowel deletion process which is both historical and productive (Clark, 1985; Lynch, 2000c; Thieberger, 2006). For the productive process used by contemporary speakers, investigations of corpus data show that short vowels are frequently deleted when they occur in the penultimate syllable of the word, though this is mediated by phonotactic, grammatical, and some lexical and stylistic factors (Billington *et al.*, forthcoming, 2019). These observations raise the question of whether vowel deletion in Nafsan, when it occurs, only occurs in unstressed or weak prosodic contexts, but given that prominence patterns in Nafsan remain under-described, this has not been clearly established.

Previous work on Nafsan includes some impressions of non-contrastive stress, or lexical prominence, but without a consensus on where, or whether, there is consistent stress placement within a word. Suggested patterns include both final stress and initial stress, with some lexically-specified differences (Capell, 1935-1980; Thieberger, 2006), but the previously unclear status of vowel length has posed an additional challenge to identifying prominence patterns. As noted, recent auditory impressionistic analyses within a wider project on the Nafsan sound system suggest possible word-final prominence. This has not yet been examined experimentally beyond preliminary investigations of patterns in disyllabic words, which we build on here with additional data and analyses (Billington *et al.*, 2018). Analyses of Nafsan intonational patterns for words in different utterance and focus contexts suggest that prominence realisation may be sensitive to syntactic and pragmatic factors (Fletcher *et al.*, 2019), and show that there is a need for targeted analyses of the prosodic realisation of Nafsan words in a controlled utterance environment.

In early research on languages of central Vanuatu, Capell notes that "[i]t is the strong stress that has done much to differentiate the Efate dialects from those of the surrounding islands" (Capell, 1935-1980, p. 8), but it is not clear whether this impression is based on the perceived cues to prominence, or more general patterns of prominence assignment. Languages closely related to Nafsan are reported to have various prominence patterns, including penultimate stress in Namakir (Sperlich, 1991, p. 80), antepenultimate stress in Nguna (Schütz, 1969, p. 11), and penultimate weight-sensitive stress in Lelepa (Lacrampe, 2014, pp. 59–60). Capell observes that among languages of Efate and nearby islands, those which have a prevalence of closed syllables word-finally tend to show final prominence (Capell, 1935-1980, pp. 9–10). Similar connections have been made for languages of the Torres and Banks islands of northern Vanuatu (François, 2005, p. 451). In Nafsan, the most common syllable type is CVC, occurring 43% of the time in one sample (Thieberger, 2006, p. 58), largely due to the frequency of closed syllables word-finally.

C. Aims of the current study

There have been various different views regarding prominence patterns in Nafsan, and in order to establish a better understanding of the Nafsan phonological system, there is a need for a more systematic investigation of the prosodic realisation of Nafsan words produced in a consistent utterance context, using an approach which considers the ways this may interact with phonemic vowel length and different word structures. The primary aim of this study is to investigate whether there are phonetic differences in the realisation of vowels depending on word position, on the basis of duration, intensity, fundamental frequency, and formant frequencies, which suggest that vowels in final syllables are more prominent than those in preceding syllables. A secondary aim of the study is to examine whether phonemically long and short vowels show similar phonetic characteristics in the same word position, or are treated differently, and to what extent duration correlates with observed prominence patterns. The methodological approach used to address these aims is outlined in Section II, followed by results in Section III and concluding discussion in Section IV.

II. METHOD

A. Participants

The participants in this study were four adult speakers of Nafsan from Erakor village in Efate, Vanuatu: three men (GK, LE, MJ) and one woman (MK). All identify Nafsan as their first language, and the language they use at home. In addition, all speak the English-lexified creole Bislama, GK and LE have knowledge of English and some French, MJ and MK have knowledge of French, and all have a small amount of knowledge of language varieties spoken in other parts of Vanuatu. In Vanuatu, multilingualism of this sort is typical; Bislama is a lingua franca used by Ni-Vanuatu people across the archipelago, and an official language alongside English and French, the languages used in the education system.

B. Materials and procedures

A set of 77 two-syllable and three-syllable word forms was compiled as stimuli (shown in Appendix A). This was drawn from the Nafsan lexical database maintained by the third author, which currently has ∼3,800 entries (see Thieberger (2011b) for an earlier version) and the corpus of ∼130 narratives collected during language documentation work since the late 1990s (see e.g. Thieberger (2011a)). The words were selected to comprise only CV(C) structures (no complex onsets), and to contain phonemically long and short vowels in different word positions, to allow investigation of whether the location of long vowels within the word interacts with prominence patterns hypothesised to be related to syllable position within the word. The majority of the vowels in these words were open /a, aː/. The consonantal environment of vowels varied, but adjacent voiceless stops were preferred where possible within the available lexical data. Two-syllable words (n=46) had the structures CV.CVC, CV.CVVC, CVV.CVC, and CVV.CVVC, and three-syllable words (n=31) had the structures CV.CV.CVC, CV.CV.CVVC, CV.CVV.CVC, and CV.CVV.CVVC. Trisyllabic words are less common in Nafsan (disyllabic words are most common in the lexical database, followed by monosyllabic words (Billington *et al.*, submitted)), and there are therefore fewer lexical items available for inclusion in the stimuli, and not all combinations of syllable types are attested.

The duration values of vowels in final and non-final syllables are not directly comparable in these structures, given that non-final syllables are open and the final syllables are closed, but this combination of word structures is necessary given the frequency with which different phonotactic patterns occur in Nafsan. Though medial CVC syllables are possible, they are less frequent, and word-final CV syllables are much less common than final CVC syllables. In addition, the characteristics of non-final CV syllables are of particular interest, given that this is an environment in which vowel deletion occurs. Deletion is not attested for vowels in the word forms included as stimuli, though it is worth noting that it is challenging to compile a set of materials examining short vowels in this environment which are not deleted, given that vowel deletion is both a change that has affected large portions of the lexicon and a process that remains productive in specific morphophonological contexts. However, there are various exceptions to its occurrence, discussed in detail in Billington *et al.* (forthcoming, 2019); while some of these appear to be lexical, the main restrictions are phonotactic and grammatical. Long vowels are never deleted, and short vowels are not deleted where deletion would result in a dispreferred consonant sequence. Short vowels in various grammatical morphemes are also not deleted, most notably in proclitics on verbs, for example in the dual realis prefix /ra-/ which has been included in a number of items on the wordlist.

Each word was recorded three times in a medial frame, following a spoken prompt, with an occasional fourth repetition due to e.g. coughing or laughter. The frame was *komam util* ____ *sernrak* ‘We say ____ usually’. Recordings were made in a sheltered area during fieldwork in Erakor, and have been archived with other recordings relating to the wider project on Nafsan phonetic and phonological patterns (Billington, 2017). Data were recorded at an archival sampling rate of 96kHz and 24-bit depth, using a Zoom H6 audio recorder and a Countryman H6 headset microphone with a hypercardioid polar pattern, and downsampled to 44.1kHz 16-bit for analysis. Tokens were balanced across participants, but, as shown in Table I and Table II, they are not balanced for vowel length category and word structure, given the limitations of available lexical data and the frequency with which different structures occur. The final dataset contained 2,269 vowel tokens drawn from 942 utterances produced. All were included in analyses, though it is worth noting that nine utterances with trisyllabic target words were produced with audibly different prosodic patterns which may relate to pause phenomena and differing overall intonation.[2] Among data for disyllabic words, 91% of vowel tokens were open vowels (/a, aː/), and among data for trisyllabic words, 74% were open vowels.

TABLE I. Number of vowel tokens from disyllabic words, by word shape and vowel length.

		syll 1		syll 2	
word shape	#words	/V/	/V:/	/V/	/V:/
CV.CVC	19	229	-	229	-
CV.CVVC	10	125	-	-	125
CVV.CVC	11	-	128	128	-
CVV.CVVC	6	-	75	-	75
total tokens		**354**	**203**	**357**	**200**

TABLE II. Number of vowel tokens from trisyllabic words, by word shape and vowel length.

		syll 1		syll 2		syll 3	
word shape	#words	/V/	/V:/	/V/	/V:/	/V/	/V:/
CV.CV.CVC	11	135	-	135	-	135	-
CV.CV.CVVC	9	122	-	122	-	-	122
CV.CVV.CVC	9	102	-	-	102	102	-
CV.CVV.CVVC	2	26	-	-	26	-	26
total tokens		**385**	**0**	**257**	**128**	**237**	**148**

C. Data processing and analysis

Utterances were transcribed orthographically in Praat (Boersma and Weenink, 2018), and orthographic transcriptions were converted to phonemic transcriptions in the Speech Assessment Methods Phonetic Alphabet (SAMPA). Using the TextGrid files and associated WAV files, automatic segmentation of the speech signal was performed via the web interface of the Munich Automatic Segmentation System (WebMAUS) (Kisler *et al.*, 2017), using the language-independent model for segment identification. Segment boundaries in the output TextGrid files were checked and manually corrected where necessary with reference to wideband spectrograms and corresponding waveforms in Praat. A hierarchical database was constructed using the EMU Speech Database Management System (Winkelmann *et al.*, 2017), including tiers for the phonemic segments, syllables, and words. The acoustic and durational characteristics of vowel tokens produced in the target words were queried and analysed using the `emuR` package in R (R Core Team, 2018; Winkelmann *et al.*, 2018).

Measures of interest in this study are vowel duration (in ms), intensity (root mean square amplitude, in dB), fundamental frequency (in Hz), and first and second formant frequencies (in Hz). Reported intensity measures are relative, based on values at vowel midpoints in comparison to the values at the midpoint of the coda lateral in the word preceding the target word. For fundamental frequency (f0), measures were taken at regular 5% intervals from 5% of the way into the vowel to 95% of the way into the vowel, allowing for trajectories of 19 points. Any points with zero values, largely due to breathiness, devoicing or creakiness, were removed, resulting in 19,165 observations for vowels in disyllabic words and 20,200 observations for vowels in trisyllabic words. Statistical comparisons are based on f0 values at 25%, 50% and 75%. For first formant (F1) and second formant (F2) frequency, measures were similarly taken at regular 5% intervals for a subset of the data containing only open vowels /a, aː/, which as noted comprised the majority of the data (1,865 tokens). After removal of zero values this resulted in 19,180 observations for F1 and 19,212 observations for F2 for open vowels in disyllabic words, and 15,987 observations for F1 and 16,178 observations for F2 for open vowels in trisyllabic words. Statistical comparisons for F1 and F2 are based on values at vowel midpoints.

Data relating to the different measures were tested with linear mixed-effects models using the `lme4` package (Bates *et al.*, 2015) in R. Model selection was undertaken using the `step` function of the `lmerTest` package (Kuznetsova *et al.*, 2017). Fixed effects included in the initial full models were: syllable position (in word), phonemic vowel length, preceding place, manner and voicing of consonant, following place, manner and voicing of consonant, and vowel quality; random effects included speaker, word, word shape and syllable shape. The fixed effects used in final models for each measure were those identified via `step` as comprising the best fitting model, and these are the effects reported for each comparison in the following sections (and in full results in Appendix B and Appendix C). All models also included random intercepts for speaker and word and by-speaker random slopes for word, apart from models for f0 in disyllabic words (for which only random intercepts were retained in the output). In each case, model significance was also confirmed via a likelihood ratio test. Post-hoc analyses were undertaken using Bonferroni-adjusted p-values. Results with p values <0.05 are considered significant. Given that the primary research question relates to word-internal patterns, and given the different nature of the datasets for disyllabic and trisyllabic words, patterns for disyllabic and trisyllabic words are examined separately. Given that there was only one female participant among the four participants in this study, potential differences in f0 patterns due to differing pitch ranges are considered on the basis of individual speakers rather than according to gender; selected results are reported in semitones for each participant, and plots showing f0 as well as duration are based on values normalised across speakers using the Lobanov method.

III. RESULTS

A. Duration

Duration values for vowels in disyllabic words, shown in Fig. 1, clearly illustrate the vowel length distinction in Nafsan, as expected given that this has been recently established. The effect of vowel length category on vowel duration is significant (F(1,685) = 1566, p<0.001), and post-hoc tests show that long vowels are an estimated 62 ± 2 ms longer than short vowels in disyllabic words (p<0.001). The effect of syllable position is also significant (F(1,554) = 11.89, p<0.001), with vowels in final syllables showing a small but significant increase in duration of an estimated 5 ± 1 ms compared to those in initial syllables (p<0.001). There is also a significant interaction between syllable position and vowel length (F(1,525) = 6.93, p<0.01). Post-hoc analyses shown that phonemically short and long vowels exhibit significant and sizeable duration differences in all comparisons: long vowels in both initial and final syllables have higher duration values than short vowels in initial syllables by an estimated 67 ± 2–3 ms (p<0.001), and higher duration values than short vowels in final syllables by an estimated 57 ± 2 ms (p<0.001). There are no significant differences between phonemically long vowels occurring in initial compared to final syllables (p=1), but short vowels in final syllables are an estimated 9 ± 2 ms longer than short vowels in initial syllables (p<0.001). Though larger differences may be observed for vowels of the same quantity in initial and final syllables in data with open rather than closed final syllables, the distributions shown here suggest that any duration differences correlating with word position are much smaller than those correlating with phonemic length. Some minor effects of the manner and voicing of the preceding consonant and the place and voicing of the following consonant are also observed (see Appendix B).

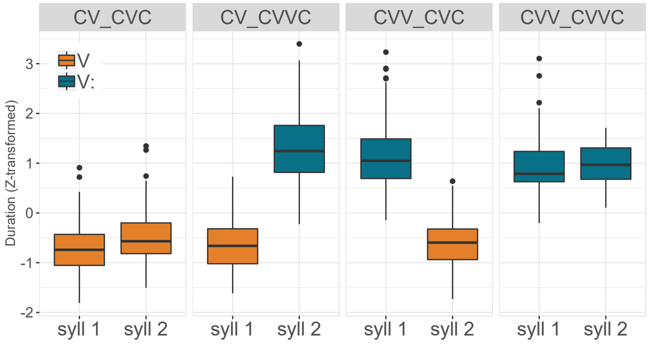

FIG. 1. (Colour online) Duration (Lobanov-normalised) of short and long vowels in initial and final syllables of disyllabic Nafsan words (by word structure).

Similar patterns are observed for vowels in trisyllabic words, with the distributions of duration values, shown in Fig. 2, also patterning according to phonemic vowel length. The effect of vowel length on duration is significant ($F(1{,}949) = 2400.28$, $p<0.001$), and long vowels are an estimated 68 ± 1 ms longer than short vowels in trisyllabic words ($p<0.001$). The effect of syllable position is also significant ($F(2{,}974) = 6.59$, $p<0.01$); while there are no duration differences between vowels in initial and medial syllables ($p=0.73$), vowels in final syllables show small but significant differences, and are an estimated 6 ± 2 ms longer than vowels in initial syllables ($p<0.01$), and 4 ± 1 ms longer than vowels in medial syllables ($p<0.01$). There was no interaction between syllable position and vowel length for vowel duration in trisyllabic words, but there were some minor effects of the place and manner of the preceding and following consonant (see Appendix C). As can be seen in Table III, long vowels in this dataset are overall approximately twice as long as short vowels in corresponding word positions.

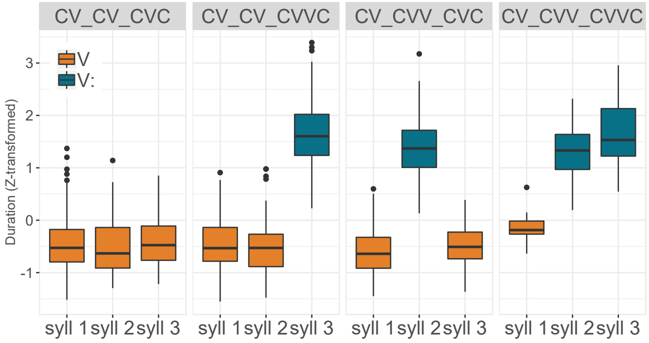

FIG. 2. (Colour online) Duration (Lobanov-normalised) of short and long vowels in initial, medial and final syllables of trisyllabic Nafsan words (by word structure).

TABLE III. Mean duration of short compared to long vowels in different word positions.

		syll 1	syll 2	syll 3
disyllables	/V/	61ms	66ms	
	/Vː/	126ms	134ms	
	ratio /V/:/Vː/	1:2.07	1:2.03	
trisyllables	/V/	60ms	58ms	62ms
	/Vː/	-	124ms	131ms
	ratio /V/:/Vː/		1:2.14	1:2.11

B. Intensity

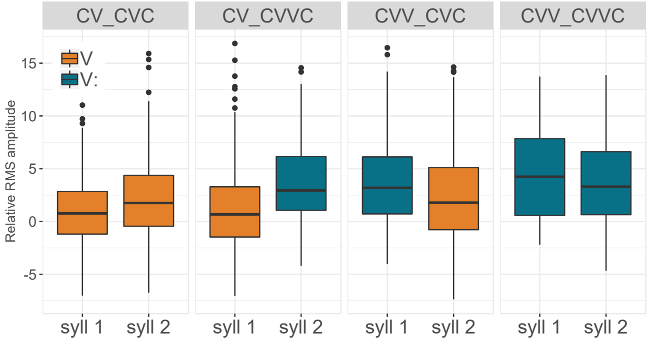

FIG. 3. (Colour online) Root mean square amplitude at midpoints of short and long vowels (relative to midpoints of lateral coda in preceding word) in initial and final syllables of disyllabic Nafsan words (by word structure).

Relative intensity patterns for vowels, based on the difference in root mean square (RMS) amplitude between the vowel midpoint and the midpoint of the lateral coda in the preceding word, are shown in Fig. 3 for disyllabic words. The effect of syllable position is significant ($F(1{,}1003) = 4.30$, $p<0.05$), but the observed difference is very small; vowels in final syllables have an increase in intensity that is an estimated 0.5 ± 0.2 dB greater than that for vowels in initial syllables ($p<0.05$). Phonemic vowel length also has a significant effect on relative intensity ($F(1{,}1106) = 67.79$, $p<0.001$), such that long vowels have relative intensity values an estimated 2.2 ± 0.3 dB higher than for short vowels ($p<0.001$). As for duration values in disyllabic words, there is also an interaction between syllable position and vowel length. Long vowels in both initial and final syllables have higher relative intensity values by an estimated 2.7–2.8 ± 0.4 dB compared to short vowels in initial syllables ($p<0.001$), and by an estimated 1.6–1.7 ± 0.3–0.4 dB compared to short vowels in final syllables ($p<0.001$). There are no significant differences in relative intensity for long vowels occurring in initial compared to final syllables ($p=1$), but intensity values for short vowels in final syllables differ from those for short vowels in initial syllables, with intensity values an estimated 1 ± 0.3 dB higher ($p<0.01$). As for duration, then, differences on the basis of RMS amplitude in disyllabic words are associated more with phonemic vowel length than syllable position. There is also a significant effect of the voicing of the following consonant ($F(1{,}1098) = 10.12$, $p<0.01$), with intensity values being slightly lower, by 0.9 ± 0.3 dB, when the following consonant is voiceless ($p<0.01$).

Relative intensity values for vowels in trisyllabic words, shown in Fig. 4, exhibit some similar patterns. In this case, syllable position was not retained as a fixed effect during

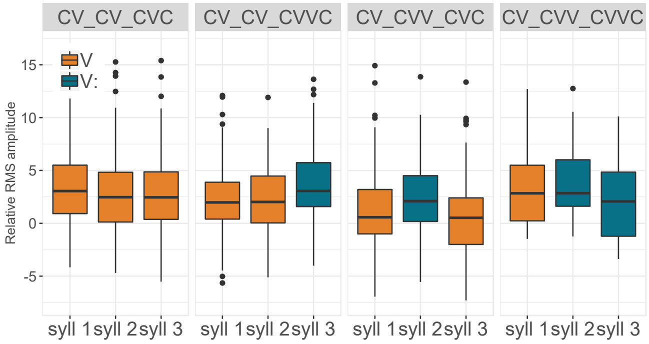

FIG. 4. (Colour online) Root mean square amplitude at midpoints of short and long vowels (relative to midpoints of lateral coda in preceding word) in initial, medial and final syllables of trisyllabic Nafsan words (by word structure).

modelling, as it did not have an effect on relative intensity. There is a significant effect of vowel length (F(1,1140) = 33.38, p<0.001), with relative intensity values for long vowels an estimated 1.5 ± 0.3 dB higher than those for short vowels (p<0.001). There is also a significant effect of the manner of the following consonant (F(3,1099) = 14.28, p<0.001), with lower intensity values observed when the following consonant is an approximant or nasal compared to a fricative or stop (see Appendix C).

C. Fundamental frequency

Smoothed f0 trajectories (based on a generalized additive model smoothing function) for vowels in disyllabic words are shown in Fig. 5, and a consistent pattern can be seen across the four word structures. The effect of syllable position is significant for f0 values at 25%, 50% and 75% points (F(1,944) = 266.30, p<0.001; F(1,953) = 348.56, p<0.001; F(1,953) = 307.06, p<0.001). Post-hoc tests confirm that there are significantly higher f0 values in final compared to initial syllables overall, of an estimated 13–15 ± 1 Hz (p<0.001). The effect of vowel length is only significant for measures at the 75% point (F(1, 404) = 8.88,

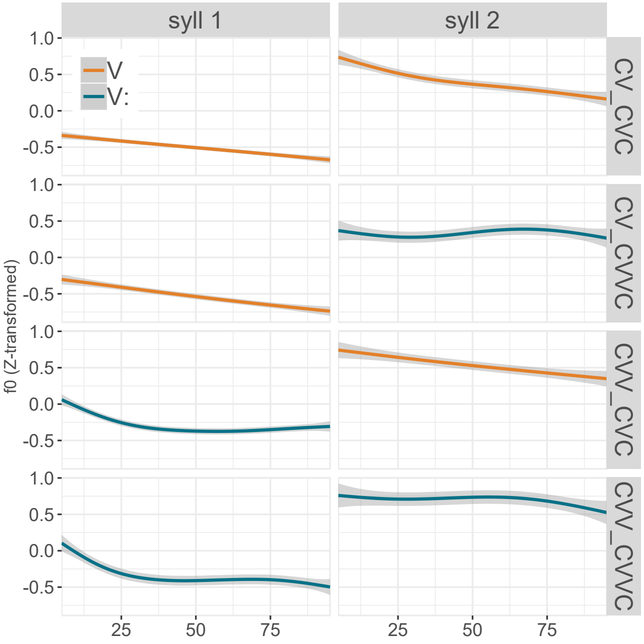

FIG. 5. (Colour online) Smoothed fundamental frequency trajectories based on 19 points (Lobanov-normalised) between 0.5%-0.95% of short and long vowels in initial and final syllables of disyllabic Nafsan words (by word structure).

$p<0.01$), with f0 values for long vowels an estimated 3 ± 1 Hz higher than f0 values for short vowels ($p<0.01$). As can be seen in Fig. 5, the smoothed trajectories for long vowels in final syllables of disyllabic words show a shallow peak in the later part of the vowel, while for short vowels this rise is absent. For measures at the 25% point, there are also significant effects of the place and manner of the following consonant ($F(3,\ 798) = 3.79$, $p<0.05$; $F(3,\ 824) = 3.96$, $p<0.01$), but few significant differences between pairs in post-hoc analyses (see Appendix B).

The f0 trajectories for vowels in trisyllabic words are shown in Fig. 6, and as for disyllabic words, there is an observable pattern of higher f0 values for vowels in final syllables. The effect of syllable position is again significant for f0 values at 25%, 50% and 75% points ($F(2{,}959) = 226.50$, $p<0.001$; $F(2{,}960) = 228.49$, $p<0.001$; $F(2{,}963) = 218.03$, $p<0.001$).

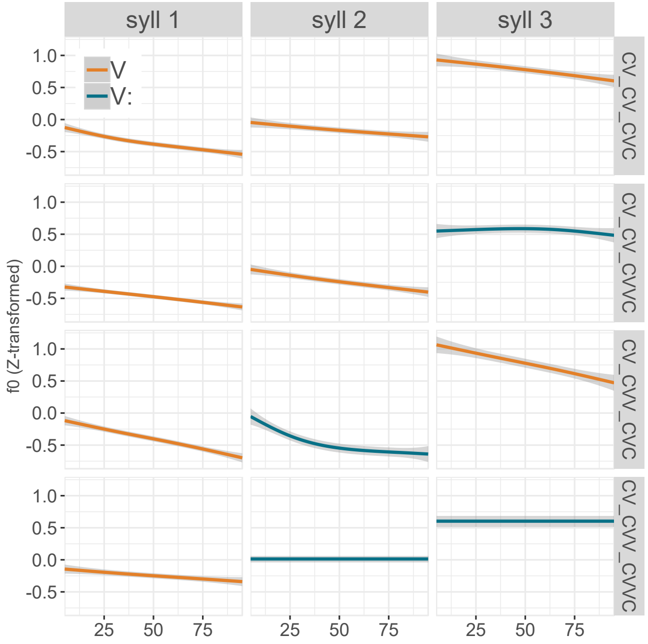

FIG. 6. (Colour online) Smoothed fundamental frequency trajectories based on 19 points (Lobanov-normalised) between 0.5%-0.95% of short and long vowels in initial, medial and final syllables of trisyllabic Nafsan words (by word structure).

There are small but significant differences in f0 values between initial and medial syllables at the 50% and 75% points, with values an estimated 3 ± 1 Hz higher in medial syllables ($p<0.05$), but larger differences are observed when comparing final syllables with medial and initial syllables. F0 values in final syllables are an estimated 16–18 ± 1 Hz higher than those in medial syllables ($p<0.001$), and an estimated 18–21 ± 1 Hz higher than those in initial syllables ($p<0.001$). The magnitude of these differences is comparable to that observed between final and initial syllables in disyllabic words. There is also a significant effect of vowel length at all three measurement points ($F(1,1043) = 28.17$, $p<0.001$; $F(1,1046) = 20.34$, $p<0.001$; $F(1,1043) = 11.95$, $p<0.001$), with f0 values an estimated 4–5 ± 1 Hz higher for long vowels compared to short vowels. No other segmental effects on f0 values for vowels in trisyllabic words are observed apart from an effect of the voicing of the preceding consonant for values at the 25% point ($F(1,\ 931) = 8.39$, $p<0.01$), with f0 values being slightly higher, by an estimated 3 ± 1 Hz, following a voiceless consonant ($p<0.01$).

F0 differences in Hz were also converted to semitones for individual participants, calculated as 12 times log base 2 of each participant's mean f0 at the measurement point of interest, e.g. the 25% point in an initial syllable, divided by their mean f0 at a comparison point, such as the 25% point in a final syllable. These are given in Table IV, and show some of the differences between individual participants. Across the four participants, differences between the final and initial syllables of disyllabic words range from 0.72–3.01 semitones. For trisyllabic words, differences between final and medial syllables range from 0.62–3.15 semitones, and differences between final and initial syllables range from 0.98–3.12 semitones.

TABLE IV. Mean differences (in semitones) between final and preceding syllables in disyllabic and trisyllabic words, for each participant.

		disyllables	trisyllables	
participant	point	syll2>syll1	syll3>syll2	syll3>syll1
GK	25%	0.80	0.64	1.07
	50%	0.74	0.64	1.01
	75%	0.72	0.62	0.98
LE	25%	1.37	1.60	1.90
	50%	1.19	1.37	1.74
	75%	0.90	1.08	1.53
MJ	25%	1.46	1.89	1.89
	50%	1.85	2.15	2.14
	75%	1.99	2.49	2.54
MK	25%	1.96	2.43	2.22
	50%	2.55	2.72	2.58
	75%	3.01	3.15	3.12

D. First and second formant frequency

Smoothed trajectories of F1 and F2 frequencies for open vowels /a, aː/ in disyllabic words are shown in Figure 7. For F1 values taken at vowel midpoints, the effect of syllable position is significant ($F(1{,}626) = 96.18$, $p<0.001$). F1 values are an estimated 61 ± 6 Hz lower for open vowels in initial compared to final syllables ($p<0.001$). There is no overall effect of syllable position on F2 values at midpoints of open vowels. There is a significant effect of vowel length on both F1 ($F(1{,}594) = 527.24$, $p<0.001$) and F2 ($F(1{,}637) = 57.45$, $p<0.001$),with F1 values an estimated 151 ± 7 Hz lower for /a/ compared to /aː/ ($p<0.001$), and F2 values an estimated 80 ± 11 Hz lower ($p<0.001$). For F1, there is also a significant interaction between vowel length and syllable position ($F(1{,}306) = 75.57$, $p<0.001$). The results of post-hoc tests show that as can be seen in Figure 7, F1 values for short /a/ in initial syllables are substantially lower than for long /aː/ in both initial and final syllables, by an estimated 217–219 ± 14 Hz ($p<0.001$). F1 values for short /a/ in final syllables are also lower than for long /aː/ in initial and final syllables, with a smaller estimated difference of 86–88 ± 10 Hz ($p<0.001$). As also observed for duration and relative intensity in disyllabic words, there are no significant F1 differences between long vowels in initial compared to final syllables (p=1), but there are differences between short vowels in initial compared to final syllables. In this case, the estimated difference is reasonably large, with F1 values 131 ± 12 Hz lower for /a/ occurring in initial syllables ($p<0.001$). For F1, there is also an effect of the place of articulation of the preceding consonant, and for F2, there are effects of the place and manner of the consonant both preceding and following the vowel, shown in Appendix B.

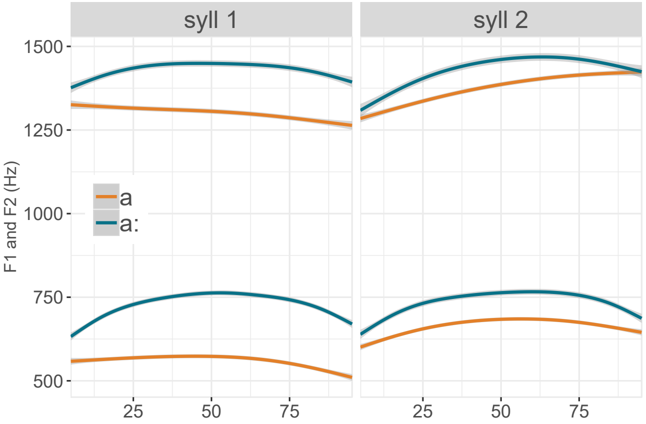

FIG. 7. (Colour online) Smoothed first and second formant frequency trajectories based on 19 points between 0.5%-0.95% of short and long open vowels in initial and final syllables of disyllabic Nafsan words.

For trisyllabic words, trajectories of F1 and F2 frequencies for /a, aː/ are shown in Figure 8. There is a significant effect of vowel length on both F1 ($F(1{,}737) = 182.17$, $p<0.001$) and F2 ($F(1{,}628) = 47.06$, $p<0.001$). As for disyllabic words, short vowels have lower values than long vowels, by an estimated 98 ± 7 Hz for F1 ($p<0.001$) and 73 ± 11 Hz for F2 ($p<0.001$). There is also a significant interaction between vowel length and syllable position in both cases ($F(3{,}549) = 18.05$, $p<0.001$; $F(3{,}419) = 4.61$, $p<0.01$). Comparing values for /a/ and /aː/ in final syllables, there is a small but significant difference in F1, with /a/ having values an estimated 35 ± 12 Hz lower than those for /aː/ ($p<0.05$). There are no significant F2 differences between /a/ and /aː/ in final syllables (p=0.80). In medial syllables, however, the largest differences in vowel quality are observed, with F1 values for /a/ an estimated 169 ± 13 Hz lower than for /aː/ ($p<0.001$), and F2 values an estimated 121 ± 19 Hz lower ($p<0.001$). There are also significant differences in both F1 and F2 between short /a/ and long /aː/ occurring in different syllable positions, as shown in Appendix C. While for disyllabic words there were no F1 differences between long /aː/ in penultimate compared to final syllables, in trisyllabic words F1 values for /aː/ are somewhat higher in penultimate syllables than final syllables, by an estimated 59 ± 13 Hz (p<0.001), though there are no significant differences in F2 (p=0.58). For short vowels, patterns in penultimate compared to final syllables are similar to results for disyllabic words in that F1 values are an estimated 90 ± 13 Hz lower for /a/ occurring in penultimate syllables (p<0.001), and additionally F2 values are an estimated 67 ± 19 Hz lower (p<0.01). Furthermore, F1 values for short /a/ are lower in penultimate compared to initial syllables, by an estimated 63 ± 10 Hz (p<0.001). As for disyllabic words, effects of the place and manner of the preceding and following consonant are also observed for measures of F2 (Appendix C).

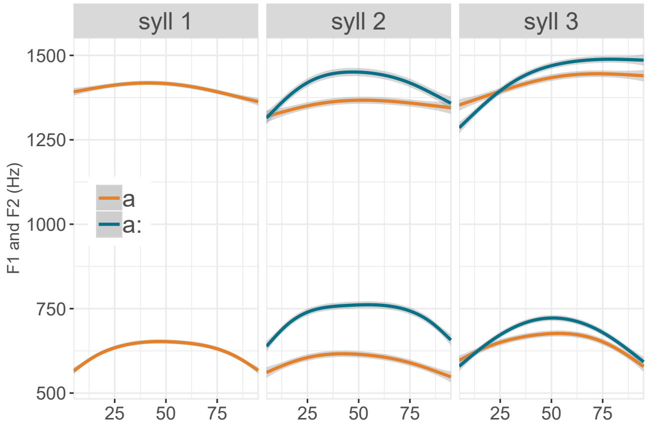

FIG. 8. (Colour online) Smoothed first and second formant frequency trajectories based on 19 points between 0.5%-0.95% of short and long open vowels in initial, medial and final syllables of disyllabic Nafsan words.

IV. DISCUSSION AND CONCLUSIONS

These findings for disyllabic and trisyllabic Nafsan words provide compelling evidence that Nafsan words tend to be produced with greater prominence at the right edge. The clear pattern of higher f0 values in final compared to preceding syllables suggests that f0 likely plays an important role in prominence marking. Across the data, vowels in final syllables have f0 values ranging from 13–21 Hz higher than those in preceding syllables. In semitones, these differences range from 0.62–3.15, and are likely perceptible in most cases, though the extent to which speakers of Nafsan are attentive to f0 cues requires perceptual investigation. There are also some small effects of vowel length, with slightly higher f0 values observed for long vowels in some comparisons. The trajectories for long vowels in at least disyllabic words also suggest possible f0 timing differences between long and short vowels in prominent syllables, which will be an interesting topic to explore in future studies focusing on prominence realisation. There are no indications, on the basis of f0 or other measures, that initial syllables are prominent in this controlled data, nor that the location of prominence is influenced by the location of long vowels within the word, as noted for some other languages in Vanuatu (Crowley, 2006).

Results for F1 and F2 at midpoints of open vowels /a, aː/ offer supporting evidence for right-edge prominence, and show that phonemic vowel length is an important factor to consider for spectral measures in different syllable positions in Nafsan. While some F2 differences are reported between vowels in different positions and of difference lengths, differences in F1 are the most notable. In examining the interactions between syllable position and vowel length for F1 values, there are significant differences in all pairwise comparisons apart from between long vowels in initial compared to final syllables in disyllabic words, but the magnitudes of these estimated differences are of interest. F1 differences between short and long vowels in final syllables are 35–86 Hz, much smaller than the F1 differences of 169–219 Hz between short and long vowels in penultimate syllables. Short vowels in penultimate syllables also have lower F1 values than short vowels in final syllables, by 75–131 Hz, and, in data for trisyllabic words, F1 values 49 Hz lower than in initial syllables. Taken together, these patterns are indicative of centralisation of short vowels in syllables preceding those with high f0 values. This is of particular interest given that short vowels in CV syllables are the site of productive vowel deletion, when it takes place (Billington *et al.*, forthcoming, 2019). Penultimate short vowels in this dataset occur in words which constitute exceptions to the widespread deletion process, but these vowels still show evidence of reduction, suggesting that this is a prosodically weak context in comparison to the word-final syllable context. Differences in vowel space peripherality for long vowels and their short counterparts across vowel qualities are currently under investigation in Nafsan (e.g. Billington *et al.* (submitted)), but indications are that the differences observed for /a/, aː/ in penultimate syllables in this data are much larger than the general tendency for short vowels to be only slightly less peripheral in monosyllabic words of different syllable types. The realisation of vowels of different qualities in different word positions and phonotactic structures will be a particularly interesting area for further research.

Duration and intensity are likely only minor cues to prominence, with significant differences on the basis of syllable position being very small. Instead, duration and to a lesser extent intensity appear to be robust correlates of vowel length and bolster recent evidence for the status of quantity distinctions in Nafsan. Phonemically long vowels show reliably and substantially greater duration values than short vowels in different contexts, of 62–68 ms. Overall, phonemically long vowels are twice as long as short vowels in this data, as also observed across all five vowel qualities in monosyllabic Nafsan words (Billington *et al.*, submitted). Across word positions, phonemically long vowels also show higher intensity values, as indicated by relative RMS amplitude at vowel midpoints, though the differences of 1.5–2.2 dB are not large. This is not unlike findings for correlates of lexical stress in some other languages with phonemic vowel length, such as Hungarian (Vogel *et al.*, 2016). While there may be larger duration differences correlating with word position in data where the final as well as initial and medial syllables are all either open or closed, it appears that in Nafsan, duration differences correlating with vowel length are likely to be well-preserved regardless of syllable prominence. Similar observations have been made based on exploratory duration measures for vowels in the closely-related language Lelepa (Lacrampe, 2014).

The results presented here accord with impressions of final prominence in Nafsan reported in some sources (Capell, 1935-1980), and in pointing towards the importance of f0 as a major correlate, also suggest the possibility that the acoustic patterns of prominence marking in Nafsan are similar to languages such as Japanese which have traditionally been described as having non-stress accent (Beckman, 1986). However, given that other ongoing research on Nafsan indicates that strong rising f0 movements at the right edge of a word may in fact demarcate the right edge of an accentual phrase (Fletcher *et al.*, 2019), it will also be worth considering whether the language has a prosodic system like that of Korean or French (e.g. Jun (1998); Jun and Fougeron (2002)), with high tone targets at right edges relating to constituents that are not necessarily lexical but phrasal. This relatively controlled data included a small number of exceptions to the overall pattern of right-edge prominence, in some cases perhaps due to pause phenomena that resulted in the tokens being produced at the beginning of intonational phrases, which would also support an analysis of phrasal rather than lexical prominence in Nafsan, although this requires further investigation. As noted in Section I A, in some grammatical descriptions of languages of Vanuatu for which no clear pattern of lexical prominence was observable, such as Daakaka (von Prince, 2015) and Nahavaq (Dimock, 2009), phrasal prominence has also been suggested, though has not yet been the subject of targeted explorations. The present results for vowels produced in an utterance-medial frame controlling for word length and syllable structure will provide a useful point of reference in ongoing work on Nafsan with more participants, which includes comparisons of the phonetic characteristics of Nafsan words of different lengths and syllable structures in utterance-initial, utterance-medial and utterance-final contexts and under different focus conditions.

Oceanic languages are under-represented in experimental prosodic research, and as crosslinguistic overviews show, there is much that remains to be understood regarding the range of prominence patterns, and phonetic cues to prominence, within this language family (Himmelmann and Kaufman, to appear, 2019; Lynch, 2000b). The Southern Oceanic languages of Vanuatu are especially well-suited to investigations of the different ways that segmental and prosodic phenomena interact, given that they show enormous diversity in their sound systems. These results show that in addition to furthering the phonetically-based description of individual languages, more detailed understandings of language-internal prosodic patterns in Oceanic languages may offer insights into the phonetic mechanisms underpinning phonological processes, while also contributing to a better understanding of the typological profile of these languages.

ACKNOWLEDGMENTS

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APPENDIX A:

TABLE V. List of disyllabic and trisyllabic Nafsan words used in materials for this study (SG=singular; DL=dual; PL=plural; RS=realis; DP=direct possession).

word shape	IPA	gloss	word shape	IPA	gloss
CV.CVC	rakat	‘bite DL RS’	CVV.CVVC	taːk͡paːr	‘sin’
CV.CVC	rapak	‘go towards DL RS’	CVV.CVVC	taːk͡poːs	‘be curved’
CV.CVC	ratap	‘be taboo DL RS’	CVV.CVVC	taːloːf	‘shake hands’
CV.CVC	ratak	‘husk coconut DL RS’	CVV.CVVC	teːŋ͡moːl	‘animal’
CV.CVC	rak͡pas	‘chase DL RS’	CVV.CVVC	waːloːp	‘crab sp.’
CV.CVC	ralat	‘cut DL RS’	CVV.CVVC	paːriːk	‘after a while’
CV.CVC	rasak	‘ascend DL RS’	CV.CV.CVC	kamarat	‘plant sp.’
CV.CVC	rapas	‘push through DL RS’	CV.CV.CVC	natatok	‘citizen’
CV.CVC	rakar	‘scratch DL RS’	CV.CV.CVC	malaŋot	‘fish sp.’
CV.CVC	ratak	‘trip DL RS’	CV.CV.CVC	nafaruk	‘wing 1SG DP ’
CV.CVC	rak͡pas	‘pick flower DL RS’	CV.CV.CVC	kalak͡poŋ	‘fish sp.’
CV.CVC	rataf	‘exit DL RS’	CV.CV.CVC	paketan	‘go down’
CV.CVC	rasak	‘sit DL RS’	CV.CV.CVC	tarisal	‘driftwood’
CV.CVC	ratas	‘shave DL RS’	CV.CV.CVC	maloput	‘middle’
CV.CVC	ralak	‘marry DL RS’	CV.CV.CVC	pakelaŋ	‘go up’
CV.CVC	rasar	‘strain DL RS’	CV.CV.CVC	tamarin	‘tree sp.’
CV.CVC	rawat	‘hit DL RS’	CV.CV.CVC	memelim	‘shellfish sp.’
CV.CVC	rawas	‘be burnt DL RS’	CV.CV.CVVC	tatakaːl	‘plant sp.’
CV.CVC	rawal	‘control canoe DL RS’	CV.CV.CVVC	tataraːs	‘plant sp.’
CV.CVVC	rapaːk	‘delouse DL RS’	CV.CV.CVVC	nalaŋaːn	‘music’
CV.CVVC	rakaːt	‘taste DL RS’	CV.CV.CVVC	maniŋ͡maːt	‘bird sp.’
CV.CVVC	rasaːk͡p	‘make mistake DL RS’	CV.CV.CVVC	nariwaːk	‘tree sp.’
CV.CVVC	rataːr	‘be white DL RS’	CV.CV.CVVC	nataŋ͡moːl	‘person’
CV.CVVC	rasaːl	‘swing DL RS’	CV.CV.CVVC	nak͡pumaːs	‘property’
CV.CVVC	rafaːr	‘pick pandanus DL RS’	CV.CV.CVVC	pakofaːm	‘shark sp.’
CV.CVVC	rawaːf	‘swim DL RS’	CV.CV.CVVC	naworaːn	‘state of being’
CV.CVVC	rawaːl	‘scoop DL RS’	CV.CVV.CVC	rataːpas	‘wave DL RS’
CV.CVVC	rasaːr	‘mix DL RS’	CV.CVV.CVC	nak͡paːk͡pak	‘banana sp.’
CV.CVVC	rulaːp	‘be many DL RS’	CV.CVV.CVC	rakaːkas	‘be sweet DL RS’
CVV.CVC	kaːkas	‘be sweet’	CV.CVV.CVC	rafaːfat	‘believe DL RS’
CVV.CVC	taːtan	‘bury’	CV.CVV.CVC	rataːsak	‘come ashore DL RS’
CVV.CVC	paːlak	‘creep up on’	CV.CVV.CVC	rataːk͡pas	‘be adopted DL RS’
CVV.CVC	kaːfat	‘fourth’	CV.CVV.CVC	ŋ͡maːrak	‘be clever’ DL RS’
CVV.CVC	taːpas	‘wave’	CV.CVV.CVC	teleːkor	‘guard’
CVV.CVC	taːsak	‘come ashore’	CV.CVV.CVC	rapaːlak	‘creep up on DL RS’
CVV.CVC	taːk͡pas	‘be adopted’	CV.CVV.CVVC	naleːnaːn	‘truth’
CVV.CVC	faːfat	‘believe’	CV.CVV.CVVC	naleːwaːn	‘feast’
CVV.CVC	naːpas	‘fish sp.’			
CVV.CVC	ŋ͡maːrak	‘be clever’			
CVV.CVC	maːlaŋ	‘recover’			

APPENDIX B:

TABLE VI. Results of comparisons (estimated difference, standard error and p-value) for measures of duration (ms), relative RMS amplitude (dB), f0 at 25%, 50% and 75% (Hz), and F1 and F2 at midpoints (Hz), for vowel tokens in disyllabic words (*** = <0.001; **= <0.01; *=<0.05).

	dur.			rel. RMS			f0 25%			f0 50%			f0 75%			F1			F2		
comparison	est	SE	*p*	est	SE	*p*	est	SE	*p*	est	SE	*p*	est	SE	*p*	est	SE	*p*	est	SE	*p*
syllable position																					
SYLL 1 ∼ SYLL 2	-5	1	***	-0.5	0.2	*	-13	1	***	-15	1	***	-15	1	***	-61	6	***	-	-	-
V length																					
V ∼ V:	-62	2	***	-2.2	0.3	***	-	-	-	-	-	-	-3	1	**	-151	7	***	-80	11	***
preceding place																					
ALV ∼ LAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	10	*	97	18	***
ALV ∼ LBV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	10	1	67	18	**
ALV ∼ VEL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	56	14	***	0	22	1
LAB ∼ LBV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-21	12	0.55	-30	21	0.86
LAB ∼ VEL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	15	0.32	-97	23	***
LBV ∼ VEL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	15	**	-67	24	*
preceding manner																					
APR ∼ FRC	-21	5	***	-	-	-	-	-	-	-	-	-	-	-	-	-107	32	**	-117	16	***
APR ∼ NSL	3	5	1	-	-	-	-	-	-	-	-	-	-	-	-	29	26	1	-57	32	0.44
APR ∼ STP	-16	4	**	-	-	-	-	-	-	-	-	-	-	-	-	-95	32	*	-99	12	***
FRC ∼ NSL	23	7	**	-	-	-	-	-	-	-	-	-	-	-	-	136	40	**	60	33	0.43
FRC ∼ STP	4	2	0.35	-	-	-	-	-	-	-	-	-	-	-	-	12	12	1	18	18	1
NSL ∼ STP	-19	6	*	-	-	-	-	-	-	-	-	-	-	-	-	-124	39	**	-42	32	1
preceding voicing																					
VCD ∼ VLS	16	4	***	-	-	-	-	-	-	-	-	-	-	-	-	102	34	**	-	-	-
following place																					
ALV ∼ LAB	-2	2	1	-	-	-	4	1	**	-	-	-	-	-	-	-	-	-	49	15	**
ALV ∼ LBV	7	2	**	-	-	-	0	1	1	-	-	-	-	-	-	-	-	-	102	18	***
ALV ∼ VEL	9	2	***	-	-	-	0	1	1	-	-	-	-	-	-	-	-	-	35	12	*
LAB ∼ LBV	9	3	**	-	-	-	-4	2	0.12	-	-	-	-	-	-	-	-	-	53	21	0.07
LAB ∼ VEL	11	2	***	-	-	-	-4	1	0.07	-	-	-	-	-	-	-	-	-	-15	18	1
LBV ∼ VEL	3	3	1	-	-	-	0	2	1	-	-	-	-	-	-	-	-	-	-67	19	**
following manner																					
APR ∼ FRC	-	-	-	-	-	-	-4	1	**	-	-	-	-	-	-	-	-	-	-14	15	1
APR ∼ NSL	-	-	-	-	-	-	-6	3	0.35	-	-	-	-	-	-	-	-	-	-133	32	***
APR ∼ STP	-	-	-	-	-	-	-2	1	0.35	-	-	-	-	-	-	-	-	-	-62	12	***
FRC ∼ NSL	-	-	-	-	-	-	-2	3	1	-	-	-	-	-	-	-	-	-	-118	31	***
FRC ∼ STP	-	-	-	-	-	-	2	1	0.78	-	-	-	-	-	-	-	-	-	-48	13	**
NSL ∼ STP	-	-	-	-	-	-	4	3	1	-	-	-	-	-	-	-	-	-	71	30	0.12
following voicing																					
VCD ∼ VLS	13	2	***	0.9	0.3	**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
syllable position : V length																					
SYLL 1 V ∼ SYLL 2 V	-9	2	***	-1.0	0.3	**	-	-	-	-	-	-	-	-	-	-131	12	***	-	-	-
SYLL 1 V ∼ SYLL 1 V:	-67	3	***	-2.8	0.4	***	-	-	-	-	-	-	-	-	-	-219	14	***	-	-	-
SYLL 1 V ∼ SYLL 2 V:	-67	2	***	-2.7	0.4	***	-	-	-	-	-	-	-	-	-	-217	14	***	-	-	-
SYLL 2 V ∼ SYLL 1 V:	-57	2	***	-1.7	0.3	***	-	-	-	-	-	-	-	-	-	-88	10	***	-	-	-
SYLL 2 V ∼ SYLL 2 V:	-57	2	***	-1.6	0.4	***	-	-	-	-	-	-	-	-	-	-86	10	***	-	-	-
SYLL 1 V: ∼ SYLL 2 V:	0	2	1	0.1	0.4	1	-	-	-	-	-	-	-	-	-	2	13	1	-	-	-

APPENDIX C:

TABLE VII. Results of comparisons (estimated difference, standard error and *p*-value) for measures of duration (ms), relative RMS amplitude (dB), f0 at 25%, 50% and 75% (Hz), and F1 and F2 at midpoints (Hz), for vowel tokens in trisyllabic words (*** = <0.001; **= <0.01; *=<0.05).

	dur.			rel. RMS			f0 25%			f0 50%			f0 75%			F1			F2		
comparison	est	SE	*p*	est	SE	*p*	est	SE	*p*	est	SE	*p*	est	SE	*p*	est	SE	*p*	est	SE	*p*
syll. position																					
SYLL 1 ~ SYLL 2	-2	1	0.73	-	-	-	-2	1	0.09	-3	1	*	-3	1	*	-	-	-	-	-	-
SYLL 1 ~ SYLL 3	-6	2	**	-	-	-	-18	1	***	-19	1	***	-21	1	***	-	-	-	-	-	-
SYLL 2 ~ SYLL 3	-4	1	**	-	-	-	-16	1	***	-17	1	***	-18	1	***	-	-	-	-	-	-
V length																					
V ~ V:	-68	1	***	-1.5	0.3	***	5	1	***	5	1	***	4	1	***	-98	7	***	-73	11	***
preceding place																					
ALV ~ LAB	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	148	15	***
ALV ~ LBV	3	2	0.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	79	18	***
ALV ~ VEL	10	2	***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42	19	0.18
LAB ~ LBV	1	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-69	22	**
LAB ~ VEL	8	2	**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-106	22	***
LBV ~ VEL	6	3	0.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-37	22	0.57
preceding manner																					
APR ~ FRC	-4	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-48	24	0.29
APR ~ NSL	-9	2	***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-90	16	***
APR ~ STP	-5	2	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-20	14	0.92
FRC ~ NSL	-5	3	0.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-42	24	0.47
FRC ~ STP	-1	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	22	1
NSL ~ STP	4	2	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	69	15	***
preceding voicing																					
VCD ~ VLS	-	-	-	-	-	-	-3	1	**	-	-	-	-	-	-	-	-	-	-	-	-
following place																					
ALV ~ LAB	4	2	0.57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	19	1
ALV ~ LBV	11	2	***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	63	16	***
ALV ~ VEL	6	2	***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	14	0.05
LAB ~ LBV	7	3	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	24	0.63
LAB ~ VEL	3	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	24	1
LBV ~ VEL	-5	2	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-27	17	0.68
following manner																					
APR ~ FRC	-4	2	0.52	2.2	0.4	***	-	-	-	-	-	-	-	-	-	-	-	-	-9	19	1
APR ~ NSL	3	2	0.72	0.4	0.3	0.94	-	-	-	-	-	-	-	-	-	-	-	-	-27	16	0.51
APR ~ STP	4	2	0.06	1.4	0.3	***	-	-	-	-	-	-	-	-	-	-	-	-	32	15	0.21
FRC ~ NSL	7	2	*	-1.8	0.4	***	-	-	-	-	-	-	-	-	-	-	-	-	-18	18	1
FRC ~ STP	8	2	***	-0.8	0.4	0.15	-	-	-	-	-	-	-	-	-	-	-	-	41	16	0.06
NSL ~ STP	1	2	1	1.0	0.3	**	-	-	-	-	-	-	-	-	-	-	-	-	59	15	***
syllable position : V length																					
SYLL 1 V ~ SYLL 2 V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49	9	***	29	14	0.25
SYLL 1 V ~ SYLL 3 V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-26	9	*	-38	16	0.13
SYLL 1 V ~ SYLL 2 V:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-120	11	***	-92	16	***
SYLL 1 V ~ SYLL 3 V:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-61	9	***	-59	16	**
SYLL 2 V ~ SYLL 3 V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-75	12	***	-67	19	**
SYLL 2 V ~ SYLL 2 V:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-169	13	***	-121	19	***
SYLL 2 V ~ SYLL 3 V:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-110	12	***	-88	21	***
SYLL 3 V ~ SYLL 2 V:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-94	12	***	-54	17	*
SYLL 3 V ~ SYLL 3 V:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-35	12	*	-22	20	0.80
SYLL 2 V: ~ SYLL 3 V:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	59	13	***	33	22	0.58

[1] Emae, Futuna-Aniwa and Mele-Fila are Polynesian (Central Pacific) languages spoken in Vanuatu, and Bislama is an English-lexified creole which is a lingua franca in Vanuatu, and English and French are learned as additional languages by many people.

[2] These nine trisyllabic word tokens with seemingly different prosodic patterns relate to five different lexical items. Three were produced by participant GK and six by participant MJ. They were not a consistent set, but the primary difference was that in these cases it was not the final syllables which were impressionistically most prominent. For the six tokens from participant MJ, the full utterance they were embedded in exhibited a marked rise on the final word *sernrak* 'usually' (which followed the target word), in comparison to the falling declarative pattern typically used by the participants. Three tokens were also produced with a pause preceding the target word. Two of the the three tokens produced by GK were also preceded by a short pause, though the three utterances maintained the overall falling intonation pattern.

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