Uncovering the acoustic vowel space of a previously undescribed language: The vowels of Nambo

Eri Kashima,[1,2] Daniel Williams,[2,3,4,a)] T. Mark Ellison,[1,2] Dineke Schokkin,[1,2] and Paola Escudero[4]

[1]*Linguistics, School of Culture, History and Language, College of Asia and the Pacific, Australian National University, HC Coombs Building #9, Acton, Australian Capital Territory 2601, Australia*

[2]*Australian Research Council Centre of Excellence for the Dynamics of Language, Australian National University, HC Coombs Building #9, Acton, Australian Capital Territory 2601, Australia*

[3]*Linguistics Department, Area of Excellence – Cognitive Sciences, University of Potsdam, Haus 14, Karl-Liebknecht-Straße 24-25, 1476 Potsdam, Germany*

[4]*The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Building 1, Bullecourt Avenue, Milperra, New South Wales 2214, Australia*

eri.kashima@anu.edu.au, daniel.williams@uni-potsdam.de, m.ellison@anu.edu.au, dineke.schokkin@anu.edu.au, paola.escudero@westernsydney.edu.au

Abstract: This study presents the first acoustic description of the vowel space of a Papuan language—Nambo, spoken in southern Papua New Guinea—based on duration and first and second formant measurements from 19 adult male and female speakers across three age groups (young, middle-aged, senior). Phonemically, Nambo has six full vowels /i, e, æ, ɑ, o, u/ and a reduced vowel tentatively labeled /ə/. Unlike the full vowels, the quality of /ə/ showed great variation: seniors' and young females' realizations tended to be more open and retracted than those by young males, while middle-aged speakers' productions fell between these two variants.

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1. Introduction

The vowels of widely documented languages, such as English, have been subject to extensive acoustic examination in order to address the phonological nature of their vowel spaces, as well as the phonetic properties of the vowels themselves (e.g., Hillenbrand *et al.*, 1995; Hagiwara, 1997). Typically, the data for these studies consist of a large number of vowel tokens from many speakers whose speech has often been recorded in carefully controlled and/or laboratory settings (e.g., Wells, 1962; Hillenbrand *et al.*, 1995; Clopper *et al.*, 2005). Descriptive linguists of lesser-documented languages, however, study the phonology of a language by working closely with a handful of native speakers—often because speaker numbers are low—and rely heavily on the impressionistic analysis of data sources which may be of variable quality. Consequently, acoustic-phonetic methods are seldom used in descriptions and analyses of such languages' phonemic inventories. Nevertheless, this situation is beginning to change and recent studies have applied acoustic-phonetic techniques in comprehensive analyses of two lesser-documented languages (Bowern *et al.*, 2012; Tabain and Butcher, 2014).

This paper presents a preliminary acoustic analysis of the vowel space for the Nambo language (glottocode namb1293, ISO-639-3, 2007) based on 904 vowel tokens collected from a sample of 19 adult speakers. Nambo is a Papuan language spoken in the southwestern part of Papua New Guinea, primarily across three neighboring villages in the Morehead District of Western Province. There are very few segmental phonetic studies on Papuan languages (but see, e.g., Dol, 2007; Schapper, 2009) and, unsurprisingly, scant information exists on the phonology of Nambo. A phonological description of the closely related language Nen (nenn1238, NQN) is available by Evans and Miller (2016).

Guided by the description of Nen and based on the relatively uncomplicated distribution of most vowels across different words in our speech sample, the Nambo vowel inventory consists of six oral vowels /i, e, æ, ɑ, o, u/, though the phonemic status of a seventh vowel, a centralized vowel tentatively labeled /ə/, is not entirely clear. It

[a)]Author to whom correspondence should be addressed.

Table 1. Speaker information.

Age Group	Age Group Determinants	Male	Female	Total
Young Adult (born 1986–1994)	Unmarried, born after Papuan Independence from Australia, speaks/understands some English.	3	3	6
Middle-Aged (≈ 1960–1979)	Married and/or provides for children, schooling received prior to or around Papuan Independence from Australia, speaks/understands English.	6	3	9
Senior (≈ 1940–1959)	Married/widowed, did not receive schooling, minimal to zero English spoken or understood. Speak/understand Motu.	3	1	4
		12	*7*	*19*

may be an "intrusive vowel," i.e., an inserted vowel that functions as a phonetic transition between consonants (Hall, 2006), or it could be a "predictable reduced vowel," as in the Papuan language Kalam (Blevins and Pawley 2010). Nevertheless, it does occur contrastively (i.e., it exists in some minimal pairs), and it exhibits acoustic structure typical of a vowel sound, substantiating a phonemic role.

2. Methods

2.1 Speakers

Nambo speakers were recruited from the village of Bevdevn (population 200) in the Morehead District of Papua New Guinea. Like many individuals in southern New Guinea, Bevdevn villagers are highly multilingual and speak at least four sister languages with varying degrees of fluency. The 19 speakers were selected to take part as they were born and raised in Bevdevn itself, so their dominant language is the village's emblematic language, Nambo. Nambo is also the language of the mothers of all but three of the 19 speakers.[1] As shown in Table 1, the speakers were divided into two gender categories and three broad age groups: young adult, middle-aged and senior. The age groups were determined by a combination of locally relevant life and age-correlated language events, as exact ages are often not known. They correspond approximately to ages 18–34, 35–49, and 50+ years old, respectively. The middle-aged and young adult groups have a working understanding of English while the middle-aged and senior groups have proficiency in Hiri-Motu (hiri1237, hmo).

2.2 Stimuli and recording procedure

Speakers were asked to carefully recite a list of suspected Nambo minimal pairs (30 words in total), repeating each item three times. Real words were used for this purpose as the phonology of Nambo is not entirely clear at present. One consequence is that consonantal context could not be systematically controlled across vowels. Instructions and list prompts were given in English: speakers fluent in this language were interviewed alone, whereas others were assisted by a family member who translated instructions and prompts into Nambo. All speakers were recorded with a Samson SE10 head-mounted microphone at a sample rate of 44.1 kHz on a Zoom H2n recorder. From the list, 13 Nambo words[2] were selected for the present study, namely, "ɑnu," "bæ," "bəmkənəm," "bombo," "dæv," "deve," "həkəv," "hure," "kɑki," "mbærmbær," "mbermber," "merez," and "tɑnde," covering the 7 vowels, yielding 904 vowel tokens (Table 2).

Table 2. Numbers of vowel tokens produced by each gender.

Vowel	Target words	Female tokens	Male tokens	Total
i	kɑki	18	35	53
e	deve, hure, mbermber, merez, tɑnde	72	138	210
æ	bæ, dæv, mbærmbær	48	73	121
ə	bəmkənəm, həkəv,	72	124	196
ɑ	ɑnu, kɑki, tɑnde,	40	75	115
o	bombo	42	61	103
u	anu, hure	39	67	106
		331	*573*	*904*

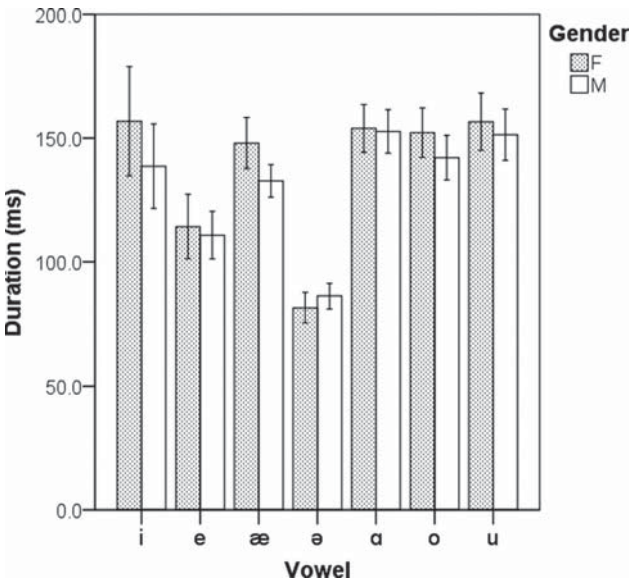

Fig. 1. Mean duration (ms) for the seven Nambo vowels separated by gender with error bars indicating the standard error.

2.3 Acoustic analysis

All vowel tokens were located in the digitized waveform by the Munich Automatic Segmentation System (MAUS) with begin- and end-points checked and manually adjusted as necessary. For every token, 30 equally spaced values of the first two formants (F1, F2) in the central 60% of each token were obtained in *Praat* (Boersma and Weenink, 2015) using the Burg algorithm with formant ceilings of 5500 Hz and 5000 Hz for female and male tokens, respectively; each set of 30 values was then fitted with second-order discrete cosine transform curves in order to yield smoother formant trajectories (Williams and Escudero, 2014). Given that the seven vowels are monophthongal, median F1 and F2 values from the smoothened trajectories were used to represent phonetic vowel quality (Moore and Carter, 2015).

3. Results

The average durations of the seven vowels are shown in Fig. 1. As is evident, /ə/ is clearly the shortest of the seven vowels with an average duration of 81.6 ms for female speakers and 86.2 ms for male speakers compared to average durations for /i, e, æ, ɑ, o, u/ of 114.2–156.7 ms for female speakers and 110.8–152.7 for male speakers.

As the left panel of Fig. 2 shows, male and female vowel tokens form roughly triangular shapes in an F1 × F2 vowel space. A closer look at averages across tokens of each vowel, as displayed in the right panel of Fig. 2, reveals the seven vowels show unambiguous separation within the Nambo acoustic vowel space, confirming the prior categorization of the tokens into /i, e, æ, ə, ɑ, o, u/. The choice of phonetic symbols for representing the seven phonemic categories in the acoustic vowel space appears to

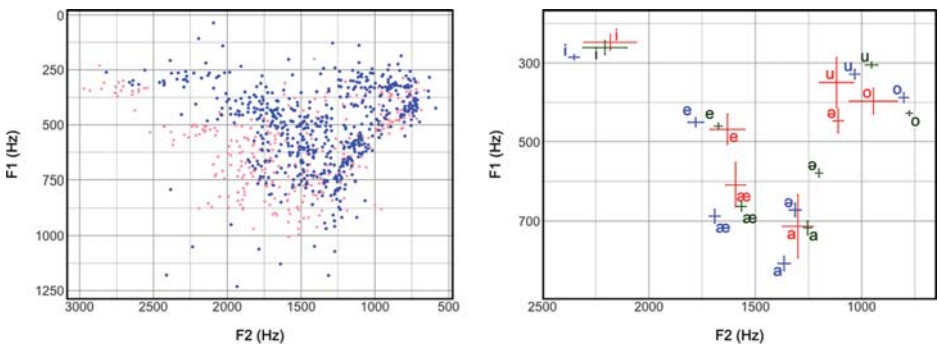

Fig. 2. (Color online) The left panel shows F1 and F2 values (Hz) of all vowel tokens (pink = F, blue = M). The right panel shows the acoustic vowel space for male speakers; that is, averages of F1 and F2 for the seven vowels per age group (red = young, green = middle-aged, blue = senior) with error bars representing the standard error.

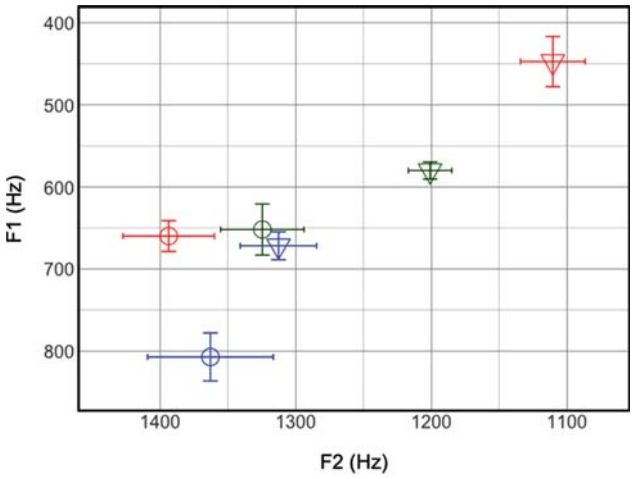

Fig. 3. (Color online) Average F1 and F2 values for the /ə/ vowel for male (triangle) and female (circle) speakers by age group (red = young, green = middle-aged, blue = senior) with error bars representing the standard error.

be more or less appropriate, though one point of concern is that there is considerably more variation in the realization of /ə/ than for the other vowels.

Given the F1 and F2 variation in /ə/, Fig. 3 displays average values for this vowel across both genders and the three age groups and reveals that the variation may be related to these social categories. Specifically, the figure suggests males of the young adult group show a more centralized pronunciation of /ə/, while the senior group and females of the young adult group exhibit a more open variant with the middle-aged group's tokens falling between the two.

4. Discussion

The present study has shown that acoustic analysis techniques can be applied in the description of the vowels of a lesser-documented language spoken in a remote part of the world with the goal of uncovering its vowel space.

In addition to substantiating the phonemic status of /i, e, æ, ɑ, o, u/, we have shed light on the status of /ə/. Although there is evidence to suggest it is a reduced vowel, e.g., its duration is considerably shorter than for the other vowels, the variability in its phonetic quality seems to pattern more with social rather than linguistic categories (Labov, 1963; Foulkes and Docherty, 2006; Hilton *et al.*, 2012; Hay and Drager, 2007). Specifically, young male and senior adults' realizations appear to stand at opposite ends of a phonetic continuum with middle-aged adults' productions being intermediate, which is reminiscent of a possible change in apparent time (Cukor-Avila and Bailey, 2013) with seemingly divergent directions for males and females.

Nevertheless, there are confounding factors to be considered further, e.g., cross-generational differences in proficiency of languages other than Nambo. Recall that younger and middle-aged speakers have some knowledge of English which was the linguistic medium used to elicit the Nambo words. Subsequent fieldwork will collect more data in order to confirm this phonetic variation and establish its conditioning factors.

To conclude, we presented acoustic data on the vowels of a hitherto undescribed Papuan language, Nambo, of southern Papua New Guinea. Despite the lack of a laboratory-quality recording environment (for a recent review of laboratory-style recording in the field, see Whalen and McDonough, 2015), the use of a head-mounted microphone permitted data-capture of sufficient quality for computational analysis.

Acknowledgments

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[1]Marriage is exogamous and it is not uncommon for women to marry into a village where a different language to their home-village is being spoken. All female speakers had not married out, except for the one female speaker in the Senior group who was visiting Bevdevn on the day of the recording.

[2]The remaining words were collected for another project. The selected 13 words were chosen primarily to reflect the range of suspected vowel qualities in Nambo as well as contain consonantal environments in which the vowel portion is relatively unambiguous to locate.

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