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Vowels in Wunambal, A Language of the North West Kimberley Region

Deborah Loakes
School of Linguistics and Applied Linguistics, The University of Melbourne
Parkville, Vic, 3010
03 9035 4777
d.loakes@unimelb.edu.au

Therese Carr
Arnhem Education Office
PO Box 446
Nhulunbuy, Northern Territory, 0880
08 8987 0886
therese.carr1@nt.gov.au

Lauren Gawne
School of Linguistics and Applied Linguistics, The University of Melbourne
Parkville, Vic, 3010
03 8344 0909
gawnel@unimelb.edu.au

Gillian Wigglesworth
School of Linguistics and Applied Linguistics, The University of Melbourne
Parkville, Vic, 3010
03 8344 4215
gillianw@unimelb.edu.au

Contact details for corresponding author:

Gillian Wigglesworth
School of Languages and Linguistics,
Babel Building
The University of Melbourne
Victoria 3010, Australia

E: gillianw@unimelb.edu.au
Tel: +61 3 8344 4215

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Biographical notes:

Therese Carr has extensive experience working with Australian Aboriginal communities in Western Australia and the Northern Territory. She provided a description of Wunambal in her Masters Thesis. Therese is currently working as an educational linguist for the Northern Territory Education Department.

Deborah Loakes is a research fellow in the School of Languages and Linguistics at The University of Melbourne. She works on languages in Australia (English and Indigenous languages) and her research interests are phonetics, phonology, sound change, and language variation and change.

Lauren Gawne is a research assistant in the School of Languages and Linguistics at The University of Melbourne. She works on the documentation and description of Tibeto-Burman languages, gesture and child language acquisition.

Gillian Wigglesworth is Director of the Research Unit on Indigenous Language, and Professor of Linguistics and Applied Linguistics at the University of Melbourne. She has worked extensively in first and second language acquisition and bilingualism. Her major research focus is on the languages indigenous children living in remote communities are learning both at home and school.

Abstract
This paper presents an acoustic phonetic analysis of a subset of vowel data from recordings of Wunambal, a Worrorran language of the Kimberly region in North West Australia. Wunambal has been analyzed as a 6 vowel system with the contrasts /i e a o u ɨ/, with /ɨ/ only found in the Northern variety. Recordings from three senior (60+) male speakers of Northern Wunambal were used for this study. These recordings were originally made for documentation of lexical items. All vowel tokens were drawn from words in short carrier phrases, or words in isolation, and we compare vowels from both accented and unaccented contexts. We have shown where the six vowels lie acoustically in relation to each other for the three speakers overall, and for each speaker individually. While all speakers in our corpus used the /ɨ/ vowel, the allophony observed suggests that the central vowel has a somewhat different phonemic status than other vowels. Accented and unaccented vowels are not significantly different for any speaker, and are similarly distributed in acoustic space.

Key words: Wunambal, acoustic phonetics, vowels

1. Introduction

1.1. Wunambal and Surrounding Languages

This paper presents an analysis of a subset of vowel data from recordings of Wunambal. Wunambal is a Worrorran language spoken in the Kimberley region in the North West of Australia (Carr 2000; McGregor 2004). This language family has twenty named varieties occurring across three subgroups; Worrorric, Ngarinyinic, and Wunambalic, to which Wunambal belongs (McGregor 2004:42). In this paper we focus on Wunambal spoken by members of Northern Wunambal clan groups.

Wunambal is a head-marking Australian language, where subject and object pronoun markers are obligatorily prefixed to the verb. It is no longer spoken as a first language by younger generations, and is now spoken by only a small number of elderly speakers (some of whom learnt it as a second language). The current version of Ethnologue (Lewis, Simons & Fennig 2014) describes Wunambal as ‘nearly extinct’ with 20 first language speakers. There are no known first language speakers of Northern Wunambal known to the researchers, three participants in this study were some of the last natives speakers of the Northern variety, and are all deceased. It is possible there are some elderly speakers of the Sothern variety still alive. There are also others who are second language speakers, or with passive or partial knowledge of both Southern and Northern Wunambal.

1.2. Vowels in Australian Languages / Vowels in Wunambal

Australian languages tend to have vowel systems with three contrasts, /i a u/. A smaller number of systems have five or six contrasts, with the addition of /e o/ being most common in five vowel systems, and the central vowel /ɨ/ being the most common addition in a six vowel system. Fletcher and Butcher (2003), and Fletcher (2005), have shown that in Dalabon (the only Australian language for which /ɨ/ has been analyzed acoustically), the central vowel is not equivalent to schwa as seen in languages like Central Arrernte (Tabain & Breen 2001) because it occurs in both accented[1] and unaccented syllables, and has a closer realization than schwa.

[1] While no intonational studies have been carried out on Wunambal, Fletcher, Round Evans and (2002: 295) note that “[m]ost Australian languages have been analyzed as having lexical stress”. Accented

Dixon (2002: 628-631) argues that these 'additional' vowels, such as /ɨ e o/, in Australian language systems have evolved from assimilation processes with neighbouring consonants, but this is a contested view with both Alpher (2005) and Sutton & Koch (2007) noting that assimilation is based on 'aprioristic grounds' (Sutton & Koch 2007: 480) rather than being evidence-based.

Wunambal has been analysed as a 6 vowel system with the contrasts /i e a o u ɨ/ (Vászolyi 1972/1973; Carr 2000; Dixon 2002), although /ɨ/ is not a feature of the Southern Wunambalic dialect which is also referred to as Wunambal (Capell 1972; Capell & Coate 1984; Carr 2000). In neighbouring Worrorra and Ngarinyin many or most instances of /e/ and /o/ can be demonstrated to occur at morpheme boundaries through morphophonemic processes (McGregor & Rumsey 2009: 21), and this also applies to some instances of these vowels in Wunambal (Carr 2000). Although morpheme boundaries may be the most common environment they appear in, monomorphemic examples can also be cited for these languages and for Wunambal, justifying their status as phonemic (see McGregor & Rumsey 2009: 22, our analysis below).

According to McGregor (2004: 90), in Wunambal a corresponding long vowel occurs for every contrast except /ɨ/ (also see Vászolyi 1972/1973 and Carr 2000), and this is also the case for another language in the Wunambalic sub-group, Kwiini. However Carr (2000) could not show easily long and short phonemic contrasts for Northern Wunambal apart from /i/-/i:/, arising predominantly at morpheme boundaries, and with possible reduced forms of two syllable prefixes and /a/-/a:/ commonly occurring in open monosyllabic words. Australian languages with more than three vowels tend to have restrictions on the environments in which additional vowels (i.e. those aside from /i a u/) can occur. One argument is that because these additional vowels have evolved from assimilation processes, they tend to be used marginally. Some examples given by Dixon are illustrative of why this might be so; for example in some languages /e/ can be derived from an underlying /i/, in others /aj/ is said to have become [e], and others still might only have these additional vowels surface in loan words (see Dixon 2002: 634-638). These restrictions mean that /i a u/ occur most frequently, and this is certainly evident in the results of the current investigation, especially with respect to /e/ and /o/ which occur marginally for all speakers, as well as /ɨ/ which occurs marginally for two of the three speakers (as will be seen below). That there is speaker variation for this vowel is not surprising; for example in Dalabon, the contrast between /ɨ/ and /u/ is not realized by all speakers (see Fletcher 2005: 212-213).

While the vowel systems of Australian languages are fairly well understood from a phonological perspective, only a relatively small amount of acoustic-phonetic research has been conducted in this area. Previous phonetic work has shown that the F1/ F2 vowel space of Australian languages is typologically compact, and that there is a significant amount of overlap between vowel types (see especially Butcher 1994; Fletcher 2005) caused primarily by coarticulatory processes from surrounding consonants (Fletcher 2005). Past research on the acoustics of vowels in Australian

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vowels, as we will refer to them, are prominent vowel that occur in lexically stressed syllables, which also carry stress accent. Unaccented vowels occur in all other syllables. Fletcher and Butcher analyzed three vowel categories (accented, unaccented and final vowels), whereas we analyzed two categories (accented and unaccented) in this first acoustic analysis of Wunambal.

languages shows that vowel tokens drawn from citation speech and/or from prosodically controlled syllables have far less overlap than those drawn from connected speech (e.g. Fletcher, Stoakes, Loakes & Butcher 2007, Harrington 2001, and Graetzer 2012 compared with Fletcher 2005).

Analysis of the vowel systems of Australian languages is important for a number of reasons. Firstly, for understanding theoretical issues in typology, an analysis of Australian language vowel systems can contribute to the way in which vowel sounds are distributed in the phonetic space. Butcher (1994) discusses the fact that the compact nature of Australian language vowel spaces means that the realization of vowels in these languages are not as dispersed as the early literature would predict. He notes that authors such as Liljenkrants & Lindblom (1972), Crothers (1978) and Disner (1984) predict a dispersion theory in which vowels are 'realized by maximally different configurations of the vocal tract' (Butcher 1994: 28). Fletcher (2005: 204) describes this as 'each vowel act[ing] as a repeller in a dynamical system'. Australian languages however, being typologically compact, and having a relatively large amount of overlap, do not accord with the idea of vowels being maximally dispersed. Rather, evidence from vowel systems of Australian languages in particular, and speaker's needs for 'articulatory economy' (Fletcher & Butcher 2003: 905) means that vowels are sufficiently dispersed in the vowel space (Fletcher & Butcher 2002; Fletcher & Butcher 2003; Fletcher 2005: 204-207; Tabain and Breen 2011).

A second reason for phonetic analysis of vowels in Australian languages is to complement the observations of field researchers. For example, Fletcher (2005: 212) showed that acoustically, /ɨ/ in Dalabon is not as close as suggested by fieldworkers, and neither is it equal to schwa. Fine-grained acoustic analysis allows an objective method to describe the way in which vowels are positioned in phonetic space, which is in turn important for contributing to theoretical discussions such as those described above. To date, no phonetic analyses have been carried out on Wunambal.

Finally, and related to the reasons above, phonetic analysis of vowels in Australian languages allows quantitative investigation of allowable variability within the system of the language, and additionally allows comparison to be made across the systems of other languages. As discussed above, these accounts may argue for phonological change based on grammar (e.g. Dixon 2002), or through comparative reconstruction (Alpher 2005; Sutton & Koch 2007). Overall, analysis of the types of variation that may occur in language, including phonetic and phonological variation, '[is] in fact fundamental to fully understand language' (Berruto 2004: 293). This includes contributions to knowledge of language as a system (and the degrees of flexibility allowed) as well as knowledge of the social function of language (Berruto 2004: 296-297).

1.3. The Present Investigation

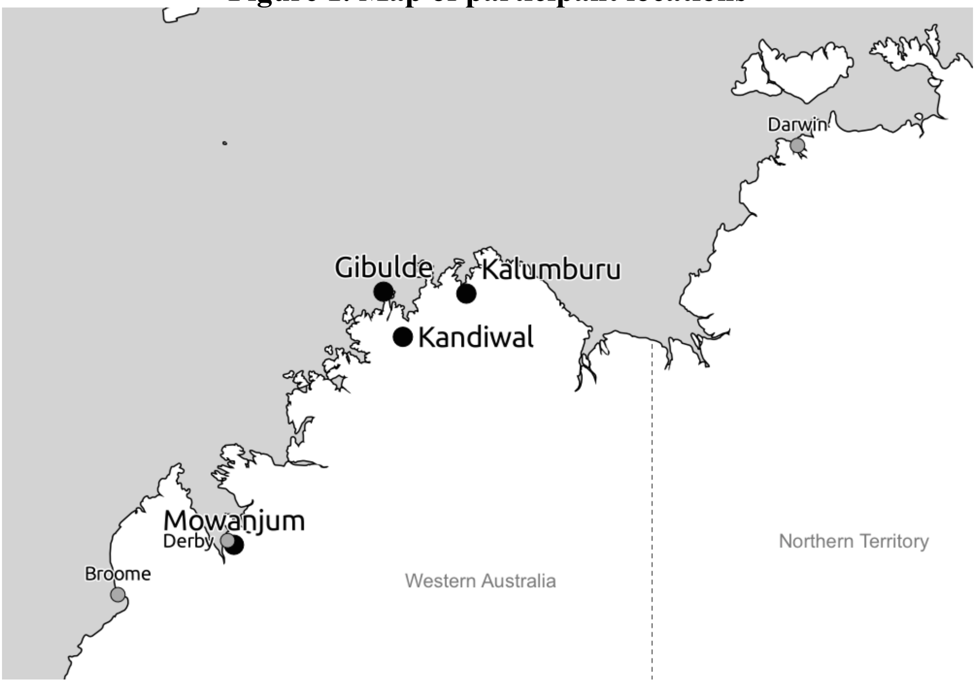
In this investigation, we describe the six vowels in Wunambal, and use acoustic phonetic analysis to illustrate how these vowels are dispersed. This is done to determine the major groupings of the vowel phonemes in Northern Wunambal, which to date have only been described impressionistically. We also analyze variation in the distribution of these vowels, focusing across accented and unaccented vowels, and on speaker variation. Finally, we relate the findings to previous work that has used acoustic-phonetic analysis to describe vowel systems of Australian languages, and address how our findings fit within theoretical issues in typology.

2. Methodology

2.1. Participants

Recordings from three senior (60+) male speakers, JK, LS and WG were used for this study. All speakers can be classified as Northern Wunambal speakers. JK and LS were brothers who were both living at Kalumburu at the time of recordings and members of the Layo clan associated with Gibulde/Cape Voltaire (see Figure 1). WG was a Wunambal elder-speaker who lived in the mixed Ngarinyin, Wunambal and Worrorra community at Mowanjum near Derby in Western Australia and on his ancestral country at Kandiwal, on the Mitchell Plateau. WG participated in the original investigation (see immediately below) on the proviso that he was doing this for 'the grandchildren'.

Figure 1. Map of participant locations



2.2. Recording and Data Collection

The data used in this paper was gathered by the first author in the course of research between 1996 and 2005. Recordings were made in Western Australia between 1996 and 2002 at Mowanjum near Derby, and in Kalumburu in 2005. Recordings from Derby were first audio-taped and later digitized, while the Kalumburu recordings were made directly onto digital audio tape. The recordings were designed to check pronunciation of Wunambal phonemes, to elicit vocabulary, and to confirm lexical items in existing transcriptions.

The 2005 recordings of JK and LS were made with participation of children from Kandiwal who travelled to Kalumburu for contact with remaining speakers of Wunambal. They were making a video learning resource with their home tutors,[2] a community artist project coordinator and the first author (a linguist) about Wunambal seasons during their school holiday break. JK and LS talked with the children about

[2] The children attend *School of the Air*.

the features of the seasons and what could be hunted or gathered at different times of the year. In simultaneous audio-recordings of these sessions, noun classes of each noun were elicited (i.e. with the appropriate carrier demonstrative) in order to document this feature of the language, especially for new vocabulary not previously recorded.

For the current analysis, all vowel tokens were drawn from words in short carrier phrases, or words in isolation. We selected short phrases that translate as 'this is xxx', where xxx is the lexical token that was sought. Wunambal has a 5-way noun class distinction, which means that the form used for the demonstrative in the carried phrase varies depending on the class of the noun. eg. *binya* 'this' (B-class), *anya* 'this' (A-class), *minya* 'this' (M-class), *winya* 'this' (W-class) and more rarely *ninya* 'this' (N-class). Examples of the structure types elicted are given below:

1) *mee* *minya*
veg.food(generic) this.M-class
'this food (vegetable).'

jebarra *anya*
emu A-class
'this emu'

We also made use of instances where the speaker repeated vocabulary items in isolation. As such, the data used in this paper is largely nouns and proximal demonstratives, and therefore (synchronically) mono-morphemic words.

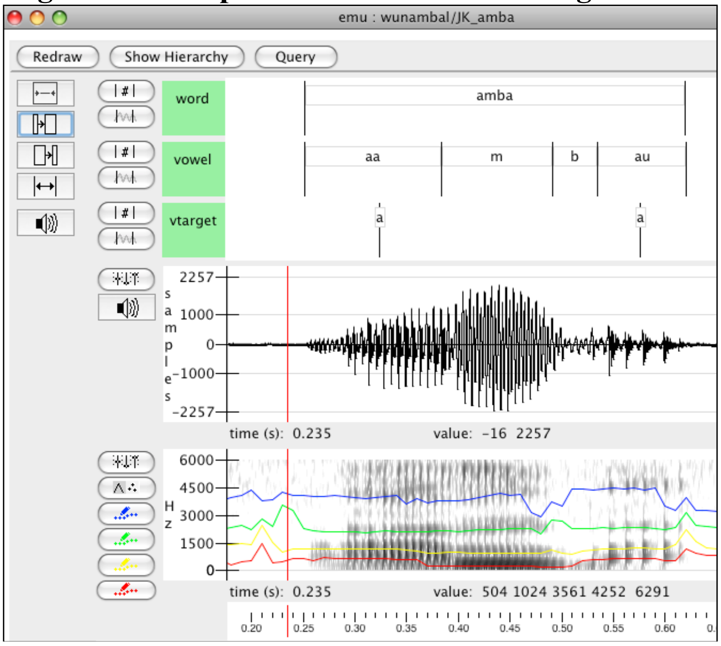
2.3. Labelling of Phonetic Data

Segments were labelled by the second author using the *EMU Speech Database System* (v.2.1.1). Next, spectral information was extracted and statistics and graphical representations were generated using *R* (v.2.8.1).[3] EMU allows user-defined multi-tiered labelling, and for this investigation we used the tiers *word, vowel* and *vtarget* ('vowel target'). Following Fletcher and Butcher (2003), we compare vowels from both accented and unaccented contexts. We use orthographic symbols to represent vowels in the images used throughout this paper because EMU allows only a machine-readable phonetic alphabet. As such, we use 'i e a o u' for /i e a o u/ and following Fletcher and Butcher (2003) we use 'V' to represent the high central vowel /ɨ/, and suffixes 'a' and 'u' to represent accented and unaccented vowels respectively.

An example of the labelling used in the investigation is shown in Figure 2 below, in the word *aamba* (kangaroo) produced by speaker JK. The omission of the initial long vowel in the transcription (amba) is discussed below. Here it can be seen that 'aa' is used to represent an accented /a/ vowel (amba), while 'au' is used to represent an unaccented /a/ vowel (amba).

[3] While EMU was used for the analysis, Praat (v. 5.1.16) was used to create the image seen in Figure 7.

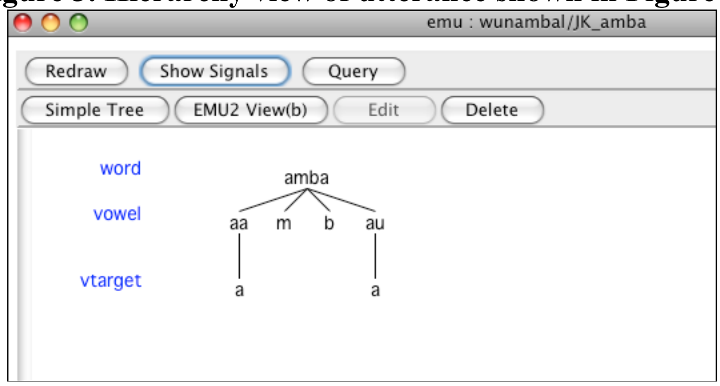
Figure 2. Example of multi-tiered labelling in EMU



Here it can be seen that the *word* and *vowel* tiers were segments, with a defined start and end point, while the *vtarget* (vowel target) tier was placed at the target (or steady-state) of the vowel. Harrington (2010: 179) describes this target as 'the section of the vowel that is least influenced by consonantal context, and most similar to a citation form production', and notes that this target may be the midpoint of the vowel, but not necessarily. Two targets are seen marked in *amba* in Figure 2. For the current investigation, all targets were hand-labelled, and a decision was made about where to place the target on a case-by-case basis.

An advantage of using EMU is that the program allows users the opportunity to create a hierarchy which connects the multi-tiered labels and allows complex searching. The hierarchy view of the utterance shown in Figure 2 can be seen in Figure 3 below.

Figure 3. Hierarchy view of utterance shown in Figure 2.



Setting up the hierarchy in this way means that it was possible to extract information from all tokens of a particular vowel phoneme (which we did to determine token frequency). It also meant that we could narrow the search and extract target values from, for example, all accented /a/ vowels, or all unaccented /a/ vowels (which we did to determine F1 and F2 values of these different categories).

Vowel information was extracted both across the corpus (for all speakers) and for individual speakers to describe the quantity and quality of vowels in the corpus. Using *R*, token counts were performed and F1/ F2 measurements were collected at vowel targets. Some statistical analyses (t-tests) were performed, and graphic displays (F1/ F2 and ellipse vowel plots, as well as boxplots) were also produced.

We note that in this study, we did not attempt to separate short and long vowels. Overall, there were only a very small number of long /i/ and /a/ vowels in the corpus which were included in the phoneme category for the short vowels. As discussed below, vowel length in Wunambal is not clearly contrastive, and so for the purposes of this study we grouped them together.

3 Results and Discussion

3.1. Evidence of Wunambal Vowel Contrasts

In this section we provide lexical evidence for place of articulation contrasts between Wunambal vowels. As discussed above, Wunambal is described as a six-vowel language with /i e a o u ɨ/ as contrasting phonemes in the Northern variety analyzed in this paper. With the exception of the restricted sixth vowel /ɨ/ Wunambal displays a vowel phoneme inventory similar to that of other Worrorran languages.

The contrasts between /i e a/[4] are easiest to observe from the lexicon, where we see minimal pairs for two of the contrasts in (1) and (2) and a minimal pair based on long vowels in (3).

2) /i/ and /u/
*b**i**marr* 'banksia'
*b**u**marr* 'his/her kidney'

3) /a/ and /u/
*b**a**ngga* 'she is'
*b**u**ngga* 'that'

4) /a/ and /i/
naa 'you'
nii 'think'

The other contrasts that exist are more constrained than the three vowel contrast above. There is a contrast between /a/ and /e/, although Carr (2000) notes a relationship between them as some forms of a>e may be the result of a notional {-y} or {yi} suffixation.

5) /a/ and /e/
*gal**a*** 'that' (W-class)
*gal**e*** 'then'

6) /o/ and /u/

[4] In Carr (2000) /i/ is analyzed as not occurring word initially, with *yi* being used in the orthography instead.

*b**o*** ‘axe handle (wattle type)’
*b**uu*** ‘blow’ (cv.)
*b**aa*** ‘emerge’ (cv.)

Although there are (near-)minimal sets such as (6) above that demonstrate a perception in the different places of articulation, there are also examples recorded of lexical items with free variation between /a/ and /o/, indicating that there might be some phonological variation.

7) /a/ ~ /o/
***o**rrowa* ~ ***a**rrowa* ‘pandanus’
***o**rnmol* ~ ***a**rnmal* ‘white ochre’
*gur**o**rra* ~ *gur**a**rra* cv. ‘crawling’
*b**o**(ny)joy* ~ *b**a**(ny)jai* ‘kurrajong’

Carr (2000: 17) suggests that a long [a] is produced as [o] in the contexts above, before and after non-peripherals i.e. apicals and palatals.

The final vowel phoneme to discuss is /ɨ/. Carr (2000: 21) notes that /ɨ/ is the most marginal of the vowel phonemes, occurring only word-medially, although also recorded before peripherals. This form only occurs in the Northern dialects, which is the variety spoken by the participants in the recordings for this paper. Vászolyi (1973a: 57) gave examples of minimal pairs for /ɨ/ with /i/ and /u/ in contrasts involving irrealis prefix-verb root boundaries for different verb roots:

8) /i/ and /ɨ/
*gɨn**ɨ**n* ‘it may hit thee’
*gɨn**i**n* ‘you may be’

9) /u/ and /ɨ/
*g**ɨ**nangan* ‘I may hit thee(sg)’
*g**u**nangan* ‘I may hit you(pl)’

With regard to length contrasts, unlike Worrorra and Kwini, but like Ungarinyin, length is not clearly distinctive though there are indications of either a past contrast or one resulting from either borrowing, glide elision, or other phonological processes.

10) /i/ and /ii/
*barij b**i**ndi* ‘(s)he arose’
*barij b**ii**ndi* ‘they arose’

11) /a/ and /aa/
*b**a**rra* ‘chat, tell stories’
*b**aa**rra* ‘paint’ [borrowed, Kwini]

Carr (2000) distinguishes /a/-/aa/ and /i/-/ii/*,* arising at morpheme boundaries, and with possible reduced forms of two syllable prefixes. It is possible that *iy* or *iyi* would be a better phonological representation of the latter contrast. The phonemic status of the /a/ and /aa/ distinction is based on a small number of examples, and the clearest minimal pair as given above involves a borrowing from Kwini. For these reasons we are only focusing on articulation of vowels, and not their duration in this paper.

3.2. Spectral Properties of the Wunambal Vowel Space

Having discussed phonemic vowel contrasts and some alternative phonemic inventory interpretations invoking possible length contrasts, in this section we analyze their acoustic-phonetic properties, focusing on the F1 and F2 vowel space. Before reporting individual differences by assessing each speaker's vowel space separately (measured in Hz), we analyze all three speaker's tokens together (measured in Bark)[5] to understand how vowels are distributed in Wunambal.

First we present the number of tokens in our corpus for each vowel phoneme. These are shown in Table 1 below.

Table 1. No. of tokens analysed: all speakers

Vowel	Accented	Unaccented	Total (%)
/i/	27	87	114 (13)
/e/	29	14	43 (5)
/a/	255	244	499 (55)
/o/	21	8	29 (3)
/u/	42	75	117 (13)
/ɨ/	37	63	100 (11)
Total	**411**	**491**	**902 (100)**

As can be seen, the number of tokens of each vowel in our corpus is unbalanced. Accounting for both accented and unaccented vowels, /a/ vowels occur most commonly at 55%, followed by /i/ and /u/ which both occur at a rate of 13% each. Of the 'additional' vowels, /ɨ/ occurs in only slightly fewer instances than /i/ and /u/ at 11%, while /e/ and /o/ can be described as occurring marginally in at a rate of 5% and 3% respectively. In our corpus, accented /a/ occurs at a higher rate than unaccented /a/ (62% of all accented tokens compared to 50% of unaccented tokens). Additionally, unaccented close vowels /i ɨ u/ occur at a much higher rate than their accented counterparts, while unaccented /e o/ occur very marginally overall.

The frequency of occurrence of vowels in our corpus reflects the typical distribution of vowels in Australian languages discussed above, although in our data the central vowel /ɨ/ patterns with /i u/ in terms of frequency, rather than with the other 'additional' vowels /e o/. This, however, is likely to be due to one speaker (WG) using more /ɨ/ vowels than the other two speakers, and reasons for this are addressed further below. We note that while /a/ occurs commonly in Australian languages, and thus unsurprisingly occurs at a high rate in our corpus, its high frequency in our corpus is also partly attributable to the fact that the most common carrier phrase used, *anya* xxx, contains two /a/ vowels. We note that amongst vowel initial words there is likely to be a much higher proportion of /a/ initial nouns due to a very small number of obligatory A-class prefixing bound noun stems and a much greater number of non-prefixing A-class vocabulary items (nouns) that are not prefixed/inflected, but are

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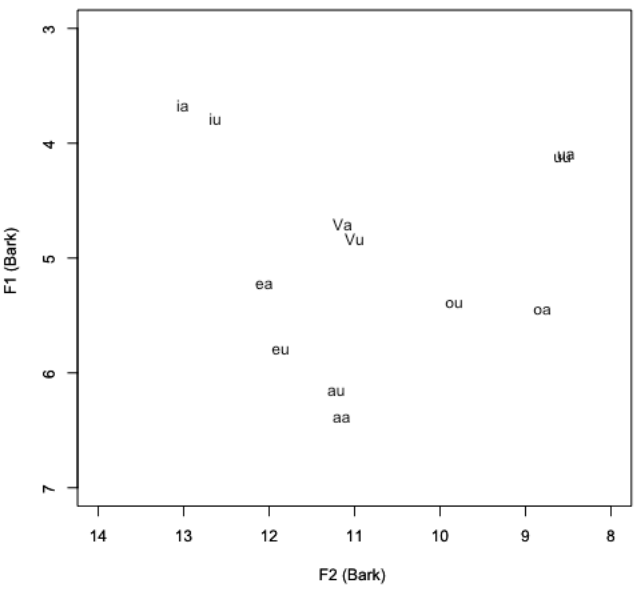
[5] Bark is an auditory scale. The benefit of using Bark over Hertz in displaying results is that it gives a better basis for plotting results together which have come from different speakers. For discussion of Bark and how it is calculated see Ladefoged and Maddieson (1996); Fletcher and Butcher (2003); Harrington (2010).

possibly derived from this type of prefixing in the past, as they too commence with /a/.[6]

Where individual speakers are concerned, token numbers are also somewhat unbalanced, with approximately 27.5% of the 902 vowels produced by JK, 31.5% by LS and 41% by WG. Actual vowel numbers produced by the speakers are reported further below.

We turn now to an F1/ F2 space showing the distribution of Northern Wunambal vowels. This space shows results from all three male speakers (similar to plots shown by Fletcher & Butcher 2003; Graetzer 2012), with individual speaker results are presented further below. Abbreviations in the figure are as described in the methodology section with the suffixes 'a' and 'u' representing accented and unaccented vowels, and 'V' representing the central vowel /ɨ/.[7]

Figure 4. Average formant frequencies (Bark): Accented vs. Unaccented Vowels[8]



The Wunambal vowel space shown here accords well with other acoustic-phonetic descriptions of vowel systems in Australian language systems, and five and six vowel systems in particular. Firstly, the space is relatively compact (e.g. Butcher 1994), which will be clearer when assessing individual speaker's vowel plots presented in Hz. As well as this, the 'additional' /e/ and /o/ vowels are essentially equidistant on the F2 dimension (Butcher 1994; also see results in Fletcher & Butcher 2002, 2003 and Fletcher et. al. 2007). However, in our data the unaccented /e/ token is acoustically much lower in the vowel space than its accented counterpart, which is most likely caused by some individual variation amongst our three speakers, given that this sound occurred so infrequently in the corpus (this is discussed in further

6 ([i] and [u] initial words on the other hand are interpreted as /y/ and /w/ initial respectively, following Dixon (1980) and others. This analysis allows for the interpretation of Australian languages as C-initial, and is more elegant than explaining why only a subset of vowels can be word initial.

7 We note that token numbers, which are shown further below for individual speakers, are unbalanced due to the nature of the data collection process. As mentioned earlier, the focus of the data collection process was not this phonetically based study.

8 Bark values for F1/ F2 are reported in the Appendix.

detail below). Another way in which this vowel space corresponds with previous work on Australian languages is that the front vowels /i e/ tend to be higher than their back vowel counterparts /u o/, and /a/ clusters toward the front of the vowel space (see results in Fletcher & Butcher 2002, 2003 and Fletcher et. al. 2007).

Interestingly, Figure 4 shows that Wunambal /ɨ/ and /a/ are equidistant in the F1 dimension. This is different to what has been found for Dalabon, the only other six vowel Australian language in which acoustic-phonetic research has been carried out. Fletcher and Butcher (2002), and Fletcher (2005), found that /ɨ/ clustered toward /u/ (i.e. Dalabon /ɨ/ is more back than our findings for Wunambal /ɨ/), and also that /ɨ/ and /u/ patterned similarly in the F1 dimension (with /ɨ/ being higher in Dalabon than Wunambal on average). In the figure above, the central vowel appears to be somewhat schwa-like in quality in Wunambal, whereas the /ɨ/ vowel in Dalabon patterns like a close vowel (see especially the discussion in Fletcher 2005: 211-212). In the Wunambal corpus however, there is speaker variation with respect to the realisation of this vowel, and this is addressed further below.

Accented vowel tokens in Wunambal tend to be more peripheral than the unaccented vowel tokens, which accords with work by Fletcher and Butcher (2002, 2003) on Dalabon, Kayardild and Bininj Gun-Wok. However, in the Wunambal data, t-tests show that none of the differences between accented and unaccented vowels is significant ($p<0.05$), nor approaching significance. This accords with Fletcher (2005), who showed that accented and unaccented vowels in Mayali, Dalabon and Kayardild were significantly different in only a small number of cases. In Dalabon and Mayali, only /a/ vowels were significantly different when comparing accented and unaccented tokens, and in Kayardild this was the case only for /aː/ (Fletcher 2005: 212). We note that in our data, the accented and unaccented /e/ and /o/ vowels pattern somewhat differently where accent is concerned, most likely because there were so few tokens overall. The differences seen for /e/ are most likely caused by individual speaker differences (mentioned earlier), while unaccented /o/ appears more central because of coarticulation (fronting) caused by palatal consonants. These factors are both discussed in greater detail below. Finally, we note that the accented and unaccented /u/ vowels in Wunambal have almost the same value, with the accented tokens being slightly more peripheral. Fletcher and Butcher (2002: 344) found a similar result, but for the low vowel /a/, in Dalabon.

3.3. Speaker Variation

In this section, we focus on the three individual speakers' realizations of the six vowel phonemes. We turn first to speaker JK, whose results are shown in Table 2 (accented vowels) and Table 3 (unaccented vowels). These tables show the number of tokens of each vowel in his data set, as well as F1 and F2 values (Hz). An F1/ F2 vowel plot of this data is shown in Figure 5, and an ellipse plot of the accented vowels is shown in Figure 6.

Table 2. Accented Vowels: Speaker JK

Vowel	No. of tokens	Mean F1 (Hz)	Mean F2 (Hz)
/i/	7	362	2066
/e/	6	471	1721
/a/	70	691	1414
/o/	8	611	1092
/u/	16	380	1025
/ɨ/	6	450	1395
total	**113**		

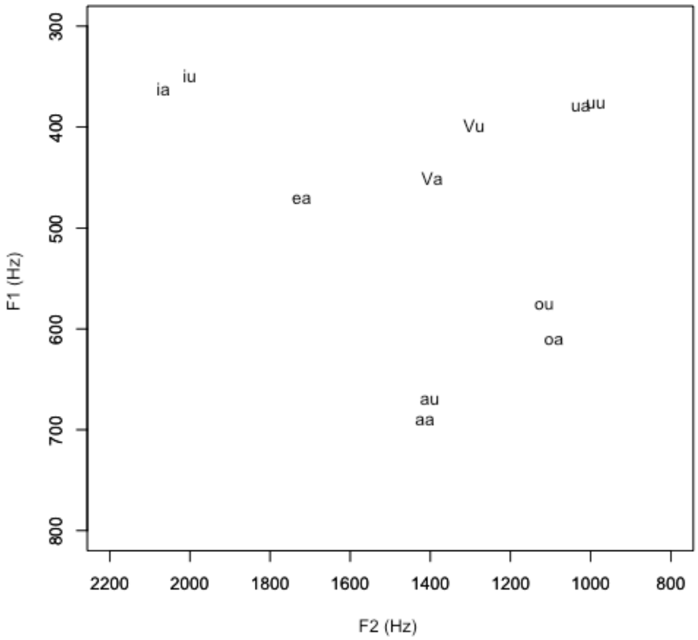
Table 3. Unaccented Vowels: Speaker JK

Vowel	No. of tokens	Mean F1 (Hz)	Mean F2 (Hz)
/i/	29	349	2000
/e/	0	-	-
/a/	71	670	1401
/o/	3	576	1116
/u/	29	376	987
/ɨ/	2	398	1291
total	**134**		

The above tables show a similar number of both accented and unaccented vowels produced by JK (113 accented tokens compared with 134 unaccented). However, the only vowel which has commensurate numbers of tokens across accented and unaccented syllables is /a/, with 70 accented and 71 unaccented tokens. Other vowels are unbalanced with regard to accent, and aside from /a/ and /u/ we note the particularly small number of accented vowels for JK, as well as unaccented /u/ and /ɨ/ tokens. We note that we observed no unaccented /e/ vowels in JK's speech.

The way these vowels are distributed is seen clearly in Figure 5 below, which is an F1/ F2 plot of all tokens drawn from JK's data set.

Figure 5. Speaker JK: Accented vs. Unaccented vowels (Hz)

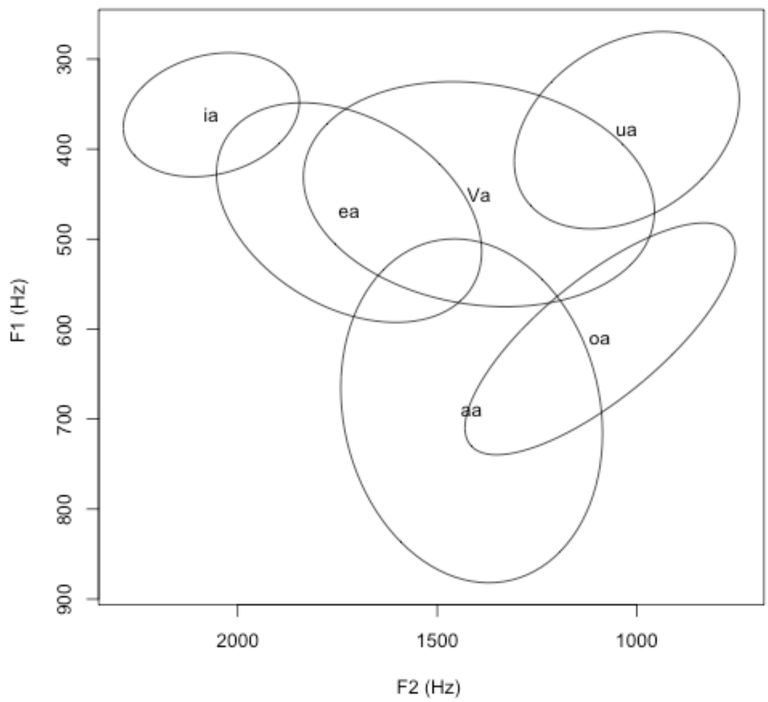


Some of the speaker variation discussed above is evident from this figure. Compared to the data shown in Figure 4, which shows F1/ F2 formant distribution for all speakers (but using a Bark rather than Hz scale as is the case here), there are some differences in how JK's vowels are distributed. Most obviously, his /e/ vowel is higher in the vowel space, and relatively close to /ɨ/ in the F1 dimension. Other differences are seen with respect to the /ɨ/ vowel, which clusters towards /u/ (similar to results reported for Dalabon by Fletcher & Butcher 2002), and is higher overall. As well as this, /a/ clusters towards the back of the vowel space rather than the front.

Differences in /e/ and /ɨ/ are due to small token numbers in JK's data set (i.e. coarticulatory influences have effected their average distribution), while his /a/ token is simply more back than in other speaker's realizations of the same vowel (this will be seen by comparison with LS and WG further below).

So far, we have only presented mean formant frequencies for JK. The ellipse plot in Figure 6 below gives an indication of formant separation and vowel 'overlap' for accented vowels produced by this speaker. Essentially, the ellipses show where 95% of all data points lie (see Harrington 2010 for detail about these plots, also see Fletcher 2005).

Figure 6. Speaker JK: Ellipse plots of accented vowels (Hz)

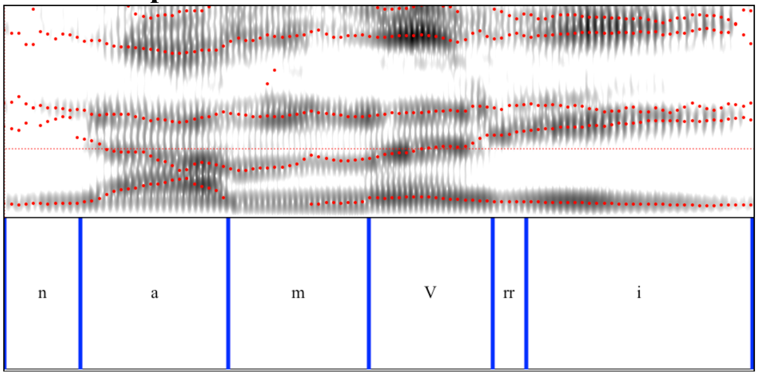


While each of the accented vowels produced by JK occupies its own expected area in the vowel space (i.e. the ellipse for /i/ is close and front, the ellipse for /ɨ/ is relatively close and central) there is a large amount of overlap between the phonemes which was not evident by analysis of mean values in Figure 5. That vowels overlap in Australian languages is not surprising, as discussed by Butcher (1994) and Fletcher (2005). However, for JK, the overlap between vowel phonemes is greater than that of other Wunambal speakers analysed (see Figure 9 for LS and Figure 11 for WG). As described by Fletcher (2005) for Mayali and Kayardild, the overlap seen in the Wunambal data is also due to consonantal coarticulatory effects (which we explore in this section). These effects are especially evident due to small token numbers for all accented vowels except /a/, and to some degree /u/.

The largest degree of overlap can be seen for the central /ɨ/ vowel (of which there are only 6 tokens for this speaker), which overlaps considerably with /e/ towards the front of the vowel space and /u/ towards the back. Additionally, JK's /o/ and /a/ vowels overlap quite considerably, similar to examples shown by Butcher (1994: 29) for a Burrarra speaker.

Assessing variation in JK's speech more closely, the range of F1 values for /ɨ/ is relatively wide, falling between 402 Hz and 522 Hz. The range of variation in F2 for this vowel is between 1205 and 1662 Hz. As will be seen, a similar amount of variation occurred in F2 of this vowel for LS, while for WG variation for /ɨ/ was observed primarily in F1. It is useful to look at each /ɨ/ token from JK's speech individually, especially as there are so few overall. Of the six tokens from observed speech, two were observed in the word *dalɨman* ('stone'), one in the word *jabɨli* (no English gloss recorded), two in *kundɨli* ('agile wallaby') and two in *namɨrri* ('wild ground honey'). Four of these had relatively back F2 values, while the two tokens drawn from *namɨrri* were fronted (1662 and 1544 Hz). This fronting is due to anticipatory coarticulation, where the vowel in the following syllable is /i/, and so F2 rises relatively steeply through /ɨ/. The consonant that intervenes between /ɨ/ and /i/ is the trill /rr/, which is actually realized as a tap. Taps are known 'to be highly sensitive to coarticulatory effects' (Recasens 1999: 84), and so it is not surprising that F2 rises throughout /ɨ/ and /rr/, and at the midpoint of /ɨ/ in *namɨrri* F2 is much higher than seen for the same vowel in other words. Also, as Graetzer (2012: 239) has demonstrated in four other Australian languages, close vowels are more likely to demonstrate coarticulatory effects. This is seen in Figure 7 below (machine readable alphabet is used here, so again 'V' represents /ɨ/).

Figure 7. Example of coarticulation between /ɨ/ and /i/ in *namɨrri*



Overlap seen between /o/ and /a/ is also due to coarticulation in F2 of /o/, caused by a following palatal consonant fronting the /o/ in six of the eight occurrences of this vowel. Fronting renders the /o/ vowel almost central on the vowel space (and thus it occurs acoustically near /a/).

We turn now to speaker LS. Token numbers and F1/ F2 measurements for each of the six vowels are reported in the tables below. Values for accented vowels are shown in Table 4, and values for unaccented vowels are shown in Table 5. An F1/ F2 vowel plot of this data is shown in Figure 8, and an ellipse plot of the accented vowels is shown in Figure 9.

Table 4. Accented Vowels: Speaker LS

Vowel	No. of tokens	Mean F1 (Hz)	Mean F2 (Hz)
/i/	17	371	1960
/e/	14	503	1802
/a/	77	637	1583
/o/	11	529	1038
/u/	5	404	1034
/ɨ/	4	375	1397
total	**128**		

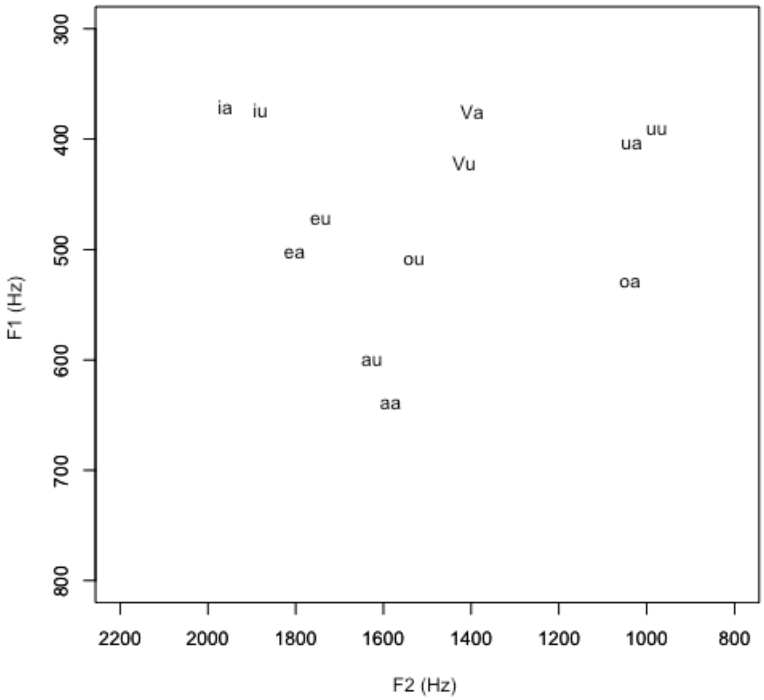
Table 5. Unaccented Vowels: Speaker LS

Vowel	No. of tokens	Mean F1 (Hz)	Mean F2 (Hz)
/i/	35	374	1880
/e/	3	472	1743
/a/	89	600	1626
/o/	3	509	1529
/u/	17	391	978
/ɨ/	9	421	1415
total	**156**		

As for JK, there are relatively similar token numbers across both conditions. Unsurprisingly given earlier discussion, and as also seen for JK, the /a/ vowel also occurs most commonly in LS's speech with 77 accented and 89 unaccented tokens. Other tokens are unbalanced, but tend to follow typical distribution patterns for Australian languages. For example, after /a/ the most common vowel for LS is /i/, of which there were 17 accented tokens and just over double the amount of unaccented tokens (35). Following this, unaccented /u/ occurs 17 times in LS's data, while only five accented tokens were observed. A relatively large number of accented /e/ tokens were produced by LS, and these 14 tokens make up almost half of the 29 accented /e/ tokens observed in the corpus overall. Aside from this, unaccented /e/ occurred marginally, as did all other vowel tokens.

An F1/ F2 plot for vowels produced by LS is seen in Figure 8 below.

Figure 8. Speaker LS: Accented vs. Unaccented vowels (Hz)



As seen from the above figure, LS's vowel space is somewhat more compact than JK's in both the F1 and F2 dimensions, and it is also more compact than WG's vowel space as will be seen (in Figure 10).

Comparing his vowel distribution with that seen in Figure 4 for all three speakers, there are only small differences with the way in which LS's vowels are distributed. Compared to the overall distribution of /ɨ/, LS has a higher realisation of this vowel, like JK, which is also reported by Fletcher and Butcher (2003) and Fletcher (2005) for Dalabon). Consequently, we can assume that WG's pronunciation of this vowel is much lower (lowering the overall average), and this will be seen further below.

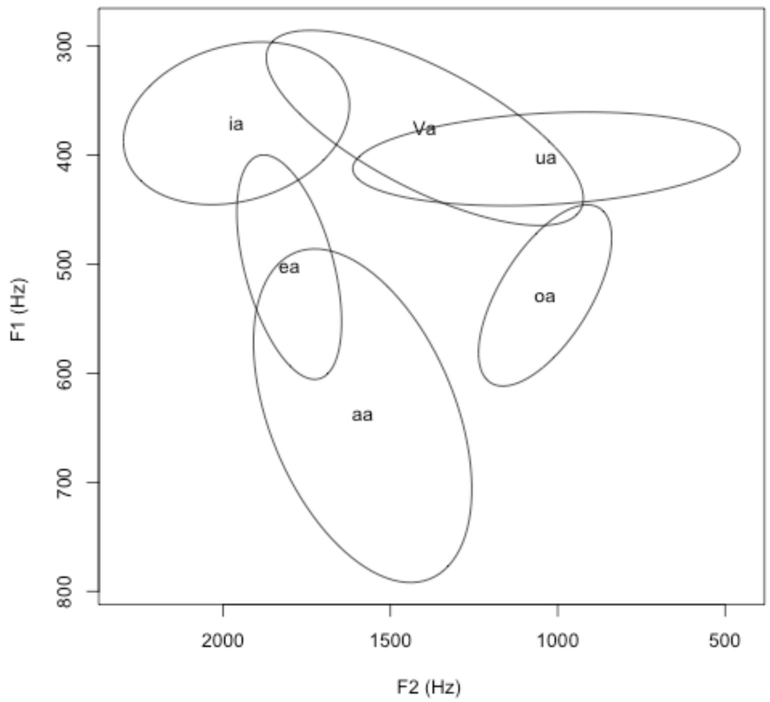
Additionally, LS has a very fronted unaccented /o/; both with respect to his accented /o/ vowel, and with respect to how unaccented /o/ appears in Figure 4 for all speakers. Two of these three unaccented /o/ tokens are the second /o/ vowel in *monyjon* (rock wallaby), while the other is the second /o/ in *gorroni* (plain kangaroo) (the other /o/

tokens in these words are accented vowels). All of these tokens have a higher than expected F2 due to coarticulation from surrounding segments. The second /o/ vowel in both occurrences of *monyjon* is affected by carryover coarticulation from the preceding palatal consonant, while the second /o/ vowel in *gorroni* is affected by anticipatory coarticulation from the /i/ vowel in the following syllable (similar to the discussion above for JK for /ɨ/ in the word *namɨrri*). As there are only three unaccented /o/ tokens overall in LS's speech, and all are affected by coarticulation from a surrounding palatal consonant, the vowel appears much more front in the vowel space than expected.

Aside from these differences, LS's vowel space is otherwise similar to the distribution seen for all speakers in Figure 4. That is, /a/ clusters toward the front of the vowel space, the close vowels /i/ and /u/ are most peripheral in the F2 dimension, and /e/ is essentially equidistant with /o/. Unlike JK's distribution of this vowel, /e/ is lower in the vowel space for LS, but the average of his /e/ vowels is not as low as seen in Figure 4 for all speakers, or a low as reported by Butcher (1994:30), who notes that F1 of /e/ often measures around 550-600Hz in Australian languages.

An ellipse plot shown below gives an indication of formant separation and vowel 'overlap' for accented vowels produced by LS.

Figure 9. Ellipse Plot of Accented Vowels: Speaker LS



Unlike speaker JK (seen in Figure 6), the ellipse plots for LS show far less overlap in the distribution of vowel categories, even though slightly more accented vowel tokens were measured in his speech (128 accented tokens compared to 113 for JK). Additionally, ellipses for the /e/ and /o/ vowels are relatively small compared to those shown for JK, varying primarily in F1. Given that more tokens of these vowels were observed in LS's speech, this suggests that coarticulatory processes have had less effect on his vowel distribution than seen for JK.

Some indication of how vowels were distributed for LS was seen in Figure 8. Following on from the discussion above though, we can now add more detail about overall distribution of accented vowels. Turning firstly to /a/, Figure 9 shows that even though the majority of his /a/ tokens were relatively high in the vowel space (close to /e/, and sometimes overlapping with /e/), some tokens were very open (with an F1 of almost 800 Hz). Unlike JK, for whom /a/ overlapped primarily with /o/, for LS /a/ overlaps primarily with the front vowel /e/. This follows from the fact that /a/ clusters towards the front of the vowel space for LS, but is more central for JK. As mentioned above, previous research has shown that overlap between /a/ and /o/ occurs in other Australian languages, and overlap between /e/ and /a/ has also been reported in productions by a Kunwinjku speaker (in Fletcher et al. 2007: 939). Additionally, Fletcher (2005: 209) shows overlap across /e a u/ in the speech of a Mayali speaker (although the overlap in that data is greater, caused by the more dynamic nature of narrative speech). As such, we can say that none of the overlap we have seen across vowel phonemes so far is particularly surprising for an Australian language. For LS, other vowels are relatively separated in the vowel space, although the central vowel /ɨ/ overlaps with both of the close vowels /i/ and /u/, rather than the pattern seen in JK's speech where /ɨ/ overlaps with /e/ and /u/, as well as /a/ to some extent.

We turn now to vowels produced by WG. The number and F1/ F2 measurements (Hz) of accented and unaccented vowels is shown in Tables 6 and 7 below, their distribution is seen in a vowel space in Figure 10, and an ellipse plot of the accented vowels is seen in Figure 11.

Table 6. Accented Vowels: Speaker WG

Vowel	No. of tokens	Mean F1 (Hz)	Mean F2 (Hz)
/i/	3	331	2109
/e/	9	641	1646
/a/	108	710	1538
/o/	2	567	950
/u/	21	436	996
/ɨ/	27	500	1562
total	**170**		

Table 7. Unaccented Vowels: Speaker WG

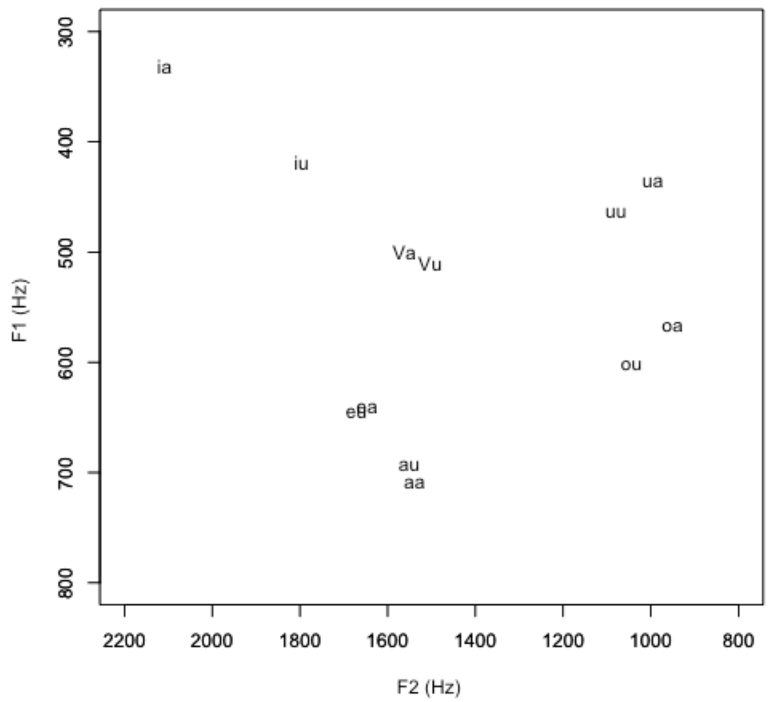
Vowel	No. of tokens	Mean F1 (Hz)	Mean F2 (Hz)
/i/	23	418	1796
/e/	11	645	1670
/a/	84	697	1551
/o/	2	602	1044
/u/	29	464	1079
/ɨ/	52	510	1503
total	**201**		

The above tables show that WG has a greater number of vowel tokens than the other speakers. As mentioned earlier, he produced 41% of vowel phonemes in the corpus. Again, the distribution of vowels is mostly unsurprising. For accented vowels, there is an especially large number of /a/ tokens, and low levels of /e/ and /o/. Interestingly however, the number of accented /i/ tokens is small compared to the number of accented /ɨ/ vowels observed (3 compared with 27). For unaccented vowels, the distribution is again mostly typical, but an exceptionally high number of /ɨ/ vowels were observed in WG's speech compared to other speakers. These 52 unaccented /ɨ/ vowels make up 25.8% of all unaccented vowel phonemes observed in WG's speech, compared to the very minimal 2 and 9 tokens observed for JK and LS respectively. More /ɨ/ tokens were observed in WG's speech occurred because he repeats words containing this vowel for the benefit of a researcher. Additionally, this phoneme occurs somewhat differently in WG's speech compared to other speakers. We observed within-speaker variation in the way WG uses the /ɨ/ vowel in both accented and unaccented contexts, and we also observed variation across speakers. For example, the first vowel of the word *minya* ('that' B-class) in LS's speech is [i], as observed across 11 occurrences of the word. For WG however, who produced the same number of tokens of this word, 4 were realized with the central vowel [ɨ], while another seven were realized with [i]. No tokens of *minya* were observed in JK's speech. Another example is that WG realizes one word with two /ɨ/ vowels, as [andɨlɨn] (cloud) in five of six repetitions, and once as [andolɨn]. We note that a small amount of variation was also seen between productions of a word by JK and LS. For JK the word [julwuny] (male euro 'hill kangaroo') was observed twice, while for LS the same word was realized twice with a central vowel as [julwɨny].

As mentioned above, not all Dalabon speakers have a contrast between /ɨ/ and /u/ vowels (Fletcher 2005), and from the examples discussed here it appears that while all three speakers produce /ɨ/ vowels, there is certainly variation in their distribution in Northern Wunambal. That is, we have described instances where /ɨ/ varies with the mid-back vowel /o/, other instances where it varies with the close back /u/ like in Dalabon, and others still where it varies with the close front /i/. Additionally, we note that while the /ɨ/ vowel was observed for all three Wunambal speakers, the distribution of the vowel (especially in the case of the demonstrative *minya*) indicates that the phoneme has a somewhat different status for WG who tends to use it more than other speakers.

The F1/ F2 distribution of WG's vowels can be seen in the figure below.

Figure 10. Speaker WG: Accented vs. Unaccented vowels (Hz)



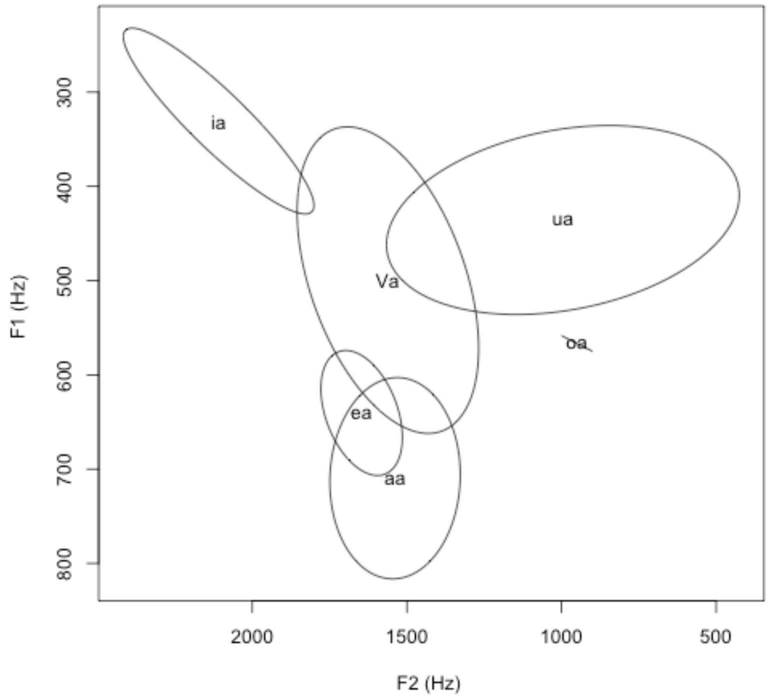
Comparing WG's vowels with those seen for other speakers, there are only small differences, to which we turn first. For WG, the accented /i/ vowel is much more peripheral than seen in previous F1/ F2 plots. This is, again, due to coarticulatory effects from surrounding palatal consonants. As seen in Table 6 above, there are only three accented /i/ tokens in WG's speech. All of these occurred in environments where a preceding or following palatal consonant caused a higher F2 measurement. Two observations were drawn from the word *minya* (the only occurrences of this word where the vowel is realized *minya* as opposed to *mɨnya*), while one was drawn from the word *wundij* (shoot, aim at, hunt).

Additionally, the mean F1/ F2 values for WG's /ɨ/ and /e/ vowels are somewhat lower in the vowel space than seen for JK and LS. As discussed above, the patterning of /ɨ/ in Wunambal is lower than seen for Dalabon. However, if we compare the distribution of this vowel across all speakers, in fact the lowered /ɨ/ occurs only for WG, whereas JK and LS have /ɨ/ vowels that are better described as close vowels (although, as discussed above, the height of the vowel also varies for JK and LS). The distribution in Figure 4 is heavily weighted towards WG's pronunciation because the majority of /ɨ/ vowels in the corpus occurred in his speech (79 of all 100 /ɨ/ tokens observed).

The /e/ vowel in WG's speech is also somewhat lower than reported by Butcher (1994: 30) for Australian languages, and lower than realizations by JK and LS. Butcher reports that values around 550-600 Hz can be expected for F1, whereas for WG F1 is 640 Hz for accented and 645 Hz for unaccented /e/, and as seen above the /e/ tokens produced by the other speakers are lower than this (and consequently higher in the vowel space).

Aside from these observations, WG's vowel space accords with other speaker's realizations. An ellipse plot for accented vowels produced by WG is shown below. As seen previously in Table 6, only 2 accented /o/ and 3 accented /i/ tokens were observed in WG's speech. We note that for /o/, the program that was used to generate plots (R) automatically drew a line rather than an ellipse because of these low token numbers.

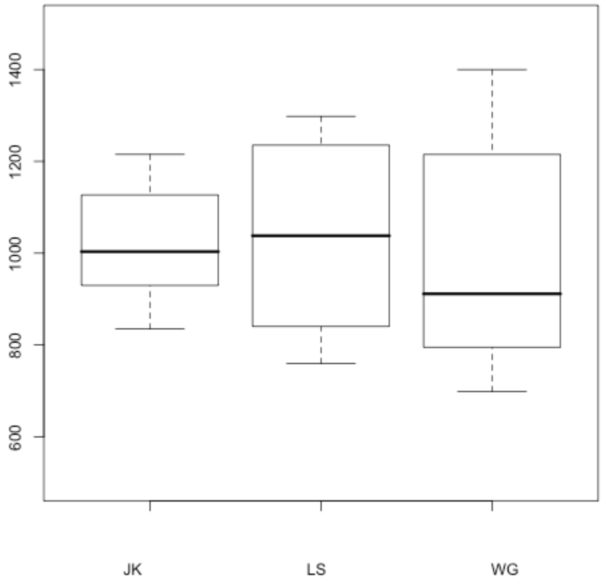
Figure 11. Ellipse Plot of Accented Vowels: Speaker WG



Compared to ellipse plots seen for JK and LS, there is less overlap in the F1/ F2 dimensions of WG's vowel space, despite the fact that in most cases he produced a greater number of vowels. In WG's speech, /a/ clusters towards the front of the vowel space and overlaps somewhat with /e/ and /ɨ/, as also seen for LS. Additionally, where the close vowels are concerned, /ɨ/ overlaps only slightly with /ɨ/ and /u/.

Regarding the variation that is evident within vowel phonemes, Figure 11 shows that /ɨ/ varies considerably in the F1 dimension (and overlaps with both the close vowels and the open vowel /a/, as discussed previously). For JK and LS, /ɨ/ varied primarily in the F2 dimension, although far fewer tokens were observed in their speech (4 and 6 accented tokens respectively, compared with 27 for WG). As mentioned further above, WG's mean F1/ F2 values for /ɨ/ appeared to be schwa-like in quality (Figure 10), but as seen from Figure 12 some tokens also fall within the region of the vowel space best described as close-central (similar to the distribution seen for other speakers). For /u/, variation is also quite considerable. Compared to both JK and LS, WG has a greater amount of variation in the F2 dimension for accented /u/ vowels, but he also produced a greater number of them. While variation for this vowel has been seen in the relevant ellipse plots, the boxplots in Figure 13 make direct comparison across speakers easier. We note that the boxes represent the 16 accented /u/ tokens produced by JK, 5 by LS and 21 by WG.

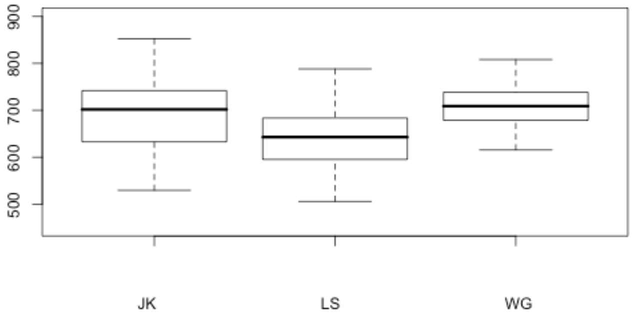
Figure 12. Boxplots of accented /u/ showing F2 variation.

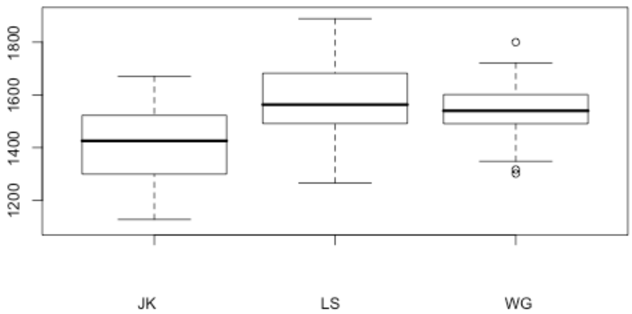


The boxplots show that most F2 variation has been observed in WG's speech, and the least in JK's. While LS only produced 5 accented /u/ tokens overall, variation is still relatively considerable. Some especially fronted tokens (i.e. a high F2) produced by WG occurred in repetitions of the words *yulyu* 'wet' (coverb) and *jujij* 'dry' (coverb) where /u/ was subject to coarticulatory effects from the following and preceding palatal consonants. Especially back tokens (a low F2) were observed in repetitions of onset /wu/ syllables in the words *wudugu* (dark night), *wulmi* (mist, fog) and *wundij* 'shoot, aim at/for' (coverb), with the labio-velar approximant having a lowering effect on F2.

For WG, ellipses for /e/ and /a/ seen in Figure 11 are small compared to the same vowels for other speakers, showing less variation in both F1 and F2. For /a/, the ellipse is remarkably small compared to what was seen for JK and LS, especially given that this represents the distribution of 95% of WG's 108 tokens. To more fully understand the range of variation seen across /a/ vowels in the corpus, the F1/ F2 distribution of each of the three speaker's accented /a/ vowels is also shown in boxplots, in Figures 13a and 13b below. The boxes in the figures represent all accented /a/ tokens for the speakers, with 77 tokens for JK, 70 for LS, and 108 for WG.

Figures 13a and 13b. Boxplots of accented /a/ showing F1 (top) and F2 variation.





For both Figures 13a and 13b, the smaller boxes and shorter whiskers show that variation is smallest across WG's accented /a/ tokens, and widest for JK, in both the F1 and F2 dimensions. The F2 boxplot for WG show three outliers for WG, but still variation is smaller than for other speakers. This shows how much variation is permissible in the vowel system for /a/ and such wide variation is common for small vowel inventories.

4. Discussion and Conclusion

The analysis of Northern Wunambal vowels presented above goes some way to describing and documenting the vowel system of an Australian language in which relatively little linguistic research has been carried out. We have reported phonetic and phonological aspects of vowel phonemes in this six-vowel language, and have discussed the conditions under which these vowels vary.

In this paper, we have seen that, overall, results accord with phonetic analyses of other Australian vowel systems (i.e. Butcher 1994; Fletcher & Butcher 2003, 2004; Fletcher 2005; Fletcher et al. 2007; Harrington 2009; Graetzer 2012). In particular, the distribution of phonemes pattern, in general, with observations from other researchers who have used acoustic analyses to determine limits of vowels in acoustic space. Additionally, our findings for Wunambal compare with Fletcher's analysis of the vowel systems of three Australian languages (Dalabon, Mayali and Kayardild). Fletcher (2005: 213) concludes that none of the three languages 'differ significantly in their overall patterning … [nor are they] significantly expanded under cases of accentuation'. This is also seen in Wunambal, where accented and unaccented vowels are not significantly different for any speaker, and are similarly distributed in acoustic space.

In the introduction, we pointed out that theoretical issues in typology are an important reason for studying the vowels of Australian languages. As discussed, previous research in this area has shown that Australian languages, with their typologically compact vowel spaces that have a relatively large amount of overlap of phonemes, does not accord with the idea of vowels being maximally dispersed, as has been shown for many other languages. Rather, in Australian language vowel spaces that have been studied acoustically, the notion of sufficient dispersion appears to be operating. The research presented here supports this. Like acoustic analyses of other Australian languages analyzed to date, the Wunambal vowel space is also typologically compact, and overlap amongst vowel phonemes is high (although, as shown, this varies somewhat according to the speaker and to consonantal context).

In the context of Australian languages, variation within the vowel system is not surprising. While we did not carry out a specific analysis of consonantal variation, it was clear in our data that variation in the vowel system occurred largely because of this, as seen in previous studies. Australian languages are typologically rich with respect to their consonant systems, which have numerous places of articulation for stops, nasals and to a lesser degree laterals (see for example Butcher 2006 for detailed discussion). This is in contrast to their vowel systems which, as mentioned, primarily consist of three vowels and never have more than six in their inventory as is the case in Wunambal. As noted by Tabain and Butcher (1999), for example, this imbalance means that consonants in Australian language phoneme systems are less free to vary than vowels. The degree of coarticulatory variation in the vowel system, which we indicated was caused by consonantal effects in Wunambal, further supports the notion that perceptual demands are much higher in Australian languages for the typologically rich consonant system. Other strategies that speakers of Australian languages employ, such as phonetically prestopped sonorants (which were also observed in the Wunambal data), are viewed as further evidence that speakers take particular care preserving spectral information at consonantal as opposed to vocalic boundaries (see Butcher 2006 for nasals, Loakes, Butcher, Fletcher & Stoakes 2008 for laterals).

Acoustic analysis of Australian languages is also important for confirming observations of field researchers. In this paper, we have confirmed the distribution of the six vowel phonemes in Northern Wunambal. We have shown where these vowels lie acoustically in relation to each other for the three speakers overall, and for each speaker individually. We have also discussed how this relates to the distribution of vowel phonemes in other Australian languages. We note that we have not attempted to address the issue of vowel length in any further detail, although this is certainly an area for further research as far as acoustic analysis is concerned, given that researchers (e.g. Carr 2000, McGregor 2004) do not agree on their presence in the system.

The distribution of /ɨ/ in the acoustic space was more variable than observed for other vowels. Additionally, both within- and between-speakers we observed allophony across repetitions of the same lexical items containing this vowel. As mentioned earlier, (Fletcher 2005: 212-213) discussed the fact that in Dalabon the contrast between /ɨ/ and /u/ is not realized by all speakers. While all speakers in our corpus used the /ɨ/ vowel, the allophony observed suggests that the central vowel has a somewhat different phonemic status than other vowels.

This study has given further insight into the vowel system of Northern Wunambal, but it has certainly not addressed all avenues of enquiry. Firstly, and as mentioned above, we have not attempted to answer the question of vowel length in this paper. Second, this paper focused on the speech of male participants only. It is possible that female speakers of Northern Wunambal used the acoustic space differently to male speakers, especially because females are traditionally more highly mobile, moving in and out of the region. For example, females marry at a relatively young age, and often adopt the language of their husband's group. Third, and as noted by Fletcher (2005: 207) 'factors like speaking rate variability, consonant context, and possibly lexical frequency effects, have to be taken into consideration in any theoretical conclusions' relating to Australian language vowel systems. We have only addressed consonantal context in the case of extreme outliers, and hope to analyze the effects of consonantal context and speaking rate in future research.

As well as these issues, we acknowledge the difficulty in obtaining a true representation of vowels that occur marginally in Australian languages, precisely because they occur so infrequently in spoken language. That is, /e o ɨ/ occurred infrequently in the data, and accurately plotting their distribution proved difficult because of this. However, the measurements we have shown for /e o ɨ/ overall, and variation within these phoneme categories, accords well with other acoustic-phonetic research on Australian languages.

In summary, acoustically analyzing the vowels of a rarely analyzed Australian language contributes to the documentation process of that language as well as to the ongoing discussion of how the vowel system of Northern Wunambal relates to other world languages.

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Appendix

Appendix 1 - F1 and F2 formant frequencies (Bark): all speakers

Vowel	F1	F2
/i/ acc.	3.67	13.01
/i/ unacc.	3.79	12.63
/e/ acc.	5.23	12.06
/e/ unacc.	5.80	11.86
/a/ acc.	6.39	11.14
/a/ unacc.	6.15	11.63
/o/ acc.	5.44	8.80
/o/ unacc.	5.39	9.83
/u/ acc.	4.10	8.52
/u/ unacc.	4.13	8.57
/ɨ/ acc.	4.71	11.14
/ɨ/ unacc.	4.83	10.99