A preliminary study of the acoustics of liquids in Wanyi

Elizabeth Rogers

Linguistics Program, EMSAH
University of Queensland, Australia
s363205@student.uq.edu.au

Abstract

This paper presents findings from a preliminary acoustic study of liquids in Wanyi, a non-Pama-Nyungan language of northern Australia. The features measured were formant frequencies and overall intensity changes across vowel—liquid—vowel (VLV) sequences, including rate of intensity change, absolute change in intensity and intensity valley alignment. The results illustrate some acoustic characteristics which contrast the liquids from one another and also give evidence for the phonemic status of the alveolar – postalveolar contrast, which has been previously contested for this language.

1. Introduction

Of the three consonant inventories proposed for Wanyi (Osborne, 1966; Stokes, 1975; Breen, 2003) only one has given the alveolar – postalveolar contrast phonemic status (Stokes, 1975). The alternative argument is that postalveolar articulations are simply the unmarked form of Wanyi apicals (Breen, 2003). The group of sounds referred to as 'liquids', a cover term for laterals and rhotics (*r*-sounds), has also generated disagreement. The variability found in transcriptions of Wanyi by different linguists also implies that impressionistically, the liquids are generally quite similar and often hard to distinguish (at least by non-native speakers). For example, the word for 'teach' has been transcribed as *mi**rl**irrimbi*, *mi**l**irrimbi* and *mi**rr**irrimbi* (Laughren, 2000 – 2005), and the word for 'steal' has been transcribed as *ngi**r**a* (Laughren, 2000 – 2005) and *ngi**rr**a* (Breen, 2003: 460). These two aspects of the Wanyi sound system form the primary motivation for the present study, a preliminary investigation of liquid contrasts and apical place contrasts.

2. Background – acoustic features of liquids

The tongue profile of laterals and the central approximant [ɹ] is such that the airway is split, thus impacting on the middle and high frequencies; this feature is one of the acoustic differences separating liquids from vowels and glides (Stevens, 1998: 532).

The term 'lateral' describes "sounds in which the tongue is contracted in such a way as to narrow its profile from side to side so that a greater volume of air flows around one or both sides than over the center of the tongue" (Ladefoged & Maddieson, 1996: 182). Prototypical acoustic characteristics of voiced lateral approximants include: low $F1$; $F2$ dependent on place of air flow blockage and tongue profile and thus often a signal to place of articulation; strong amplitude and high $F3$ but lower amplitude for the other formants; sometimes additional formants above the $F3$ which are close together; and clearer formant transitions from vowels for apicals than laminals and dorsals (Ladefoged & Maddieson, 1996: 193; Ladefoged, 2003: 145 – 147). In their acoustic model of Tamil laterals, which contrasts apico-dental [l] and apico-retroflex [ɭ], Narayanan, Byrd and Kaun (1999) attribute $F1$ for all Tamil liquids to a Helmholtz resonance in the back cavity, including the anterior tongue constriction. The $F2$, $F3$ and $F4$ of [l] are attributed to "half-wavelength resonances of the combined back and side cavities" (1999: 2002) while the $F3$ of [ɭ] is due to a front cavity resonance and is presumably responsible for the low $F3$.

Unlike the laterals, the rhotic group isn't based on similarities in manner of articulation, nor is there a common place of articulation. Lindau (1985) argues that there is also no acoustic correlate for the diverse rhotic group; however, others have argued that the correlate is a lowered $F3$, with "the lower the $F3$, the greater the degree of rhoticity" (Ladefoged, 2003: 149). While a low $F3$ is associated with central approximant [ɹ] (as evidenced by languages such as American English and West African Ịzọn (Lindau, 1985)), when talking about 'rhotic' as the cover term for a diverse group of *r*-sounds, such as taps and trills, the argument for an acoustic correlate of low $F3$ is considerably weakened. The acoustic characteristics of trills and taps are quite diverse across languages and speakers (Lindau, 1985). Formant values generally vary during the open phase of trills depending on the place of articulation. The rhotics form a phonetically heterogenous group and justifications for a class of rhotics are usually made on phonological grounds (e.g. Wiese, 2001).

Proceedings of the 11th Australian International Conference on Speech Science & Technology, ed. Paul Warren & Catherine I. Watson. ISBN 0 9581946 2 9
University of Auckland, New Zealand. December 6-8, 2006.

Accepted after abstract only review

Turning to the Australian context, one of the common phonemic features of Australian languages is that they usually have at least two rhotics, /ɹ/ and /r/ (Evans, 1995: 724). Lateral contrasts can be made at each of the four coronal places of articulation if the language makes this maximal contrast in the stops, although some languages only have a single lateral (Dixon, 1980: 143). Contrastive apicals are common in the region where Wanyi is spoken and this contrast generally extends to the laterals, as evidenced by the minimal pair in Wambaya, *bu**l**inja* 'algae' vs. *bu**rl**inja* 'to smoke' (Nordlinger, 1998: 23).

Only a limited number of acoustic studies have focused on liquids in Australian languages. One that has investigated laterals in some detail is McDonald's (2002: 46 – 67) study of Yaraldi, with the aim of both describing the acoustic properties of the various lateral articulations and assisting in clarifying phonemic distinctions. The main characteristics of postalveolar laterals [ɭ] included: falling *F*3 formant transition from the preceding vowel; *F*3 less than 2000 Hz; the occasional merging of *F*3 and *F*2; the possibility of *F*2 dropping below 1000 Hz and similarities with the alveolar lateral in terms of *F*2. The apico-alveolar laterals [l] had the properties: *F*2 between 1200 Hz and 1800 Hz but clearest after [ɐ] and with a higher frequency in this environment; *F*3 between 2000 Hz and 3000 Hz and *F*4 greater than 3000 Hz but with a small amplitude. The palatal lateral [ʎ] had a similar pattern to the high front vowel [i], with *F*2 and *F*3 greater than 2000 Hz, but quite close and with similar amplitude. Overall, clear and abrupt transitions were noted between laterals and vowels.

The aim of the present study is to investigate liquid contrasts from an acoustic perspective and to identify the effects of different vocalic environments and stress environments on the acoustic characteristics of liquids.

3. Method

3.1. Data source

The data analysed in this study were from field recordings made by Mary Laughren (University of Queensland) between 2000 and 2005 in the Northern Territory and Queensland. The main aim of these field trips was to collect grammatical data, especially focusing on aspects of the syntax and morphology. As such only a limited portion of the recordings which was suitable for use in an acoustic analysis; substantial sections of the recording were marred by interference from environmental noises and variations in the microphone position with respect to the speaker. This was an unavoidable limitation of the study, but the data were controlled as carefully as possible by only selecting sections which had a clear acoustic signal. Consequently the final data set was small.

The data were from a male speaker, aged between 70s and early 80s at the time of the recordings, which were made in an elicitation style. The speaker generally repeated words one by one after saying a sentence; these repetitions provided the clearest examples and constitute the bulk of the tokens used in the present study.

Elicitation sessions from between 2000 and 2003 were recorded on audio cassette, while the later trips were recorded on mini-disc. Cassettes were digitised by Mary Laughren using Audacity (http://audacity.sourceforge.net/) at a sampling rate of 44 kHz with a 16 bit resolution. The mini-disc recordings were converted to WAV files using Praat (Boersma & Weenink, 2006). All audio files were down-sampled to 11 kHz for use in the acoustic analysis. Words were selected for possible inclusion in the study based on Laughren's transcriptions (2000 – 2005), then segmented from the audio file using Praat.

3.2. Data sets

Two data sets were compiled. Due to the variability in orthographic representation of the words, the place and manner classification of the liquids was based on my perceptual judgements.

The first data set, shown in Table 1, included (sub-) minimal pairs which contrast various liquids. These contrasts represent the clearest tokens that could be obtained from the field recordings. The purpose of this data set was to provide an indication of which of the acoustic features measured may have been involved in the contrast.

Contrast	*n*	Minimal Pairs			*n*
[l] vs. [ɹ]	1	*kala* 'river'	vs.	*kara* 'stone'	3
[l] vs. [ɾ]	2	*nala* 'leg'	vs.	*ngara* 'hot'	4
[l] vs. [ɭ]	2	*bala* 'hook'	vs.	*barla* 'sky'	4
[l] vs. [ʎ]	2	*nala* leg'	vs.	*ngalya* 'sickness'	6
[ɹ] vs. [ɾ]	2	*bari* 'bad'	vs.	*-barri* 'now'	1

Table 1: (Sub-)minimal pairs data set contrasting liquids

The second data set, shown in Tables 2a and 2b, was compiled in order to measure Wanyi liquids in relation to two variables: vocalic environment and stress environment. Only intervocalic positions were included as liquids were acoustically most clear here, in comparison to word-initial or word-final position, or as part of a cluster. The occurrence of liquids in three symmetrical vowel frames was measured: /a_a/, /i_i/ and /u_u/. Once again this choice of environment was based on clarity considerations; these environments were the most conducive to clear formant measures.

Proceedings of the 11th Australian International Conference on Speech Science & Technology, ed. Paul Warren & Catherine I. Watson. ISBN 0 9581946 2 9
University of Auckland, New Zealand. December 6-8, 2006.

Accepted after abstract only review

The second variable tested was the position of liquids relative to word stress. Within each vocalic environment the tokens were sub-categorised according to whether they occurred before or after a stressed vowel. As no description of stress in Wanyi has been proposed, stress assignment was based on my perceptual judgements and confirmed by Mary Laughren (pers. comm., 5 September 2006). The general pattern of stress is consistent with the pattern found in many other Australian languages, where the main stress occurs on the first syllable (Evans 1995: 753). Secondary stress seems to occur on every second syllable after the main stress. Thus, in order for a consonant to be both intervocalic and before a stressed vowel, the stress must be secondary, as the consonant that occurs before a main stress is generally word initial and therefore not intervocalic. Those liquids that were categorised in the 'after stressed vowel' environment occurred after either a main stress (e.g. *wu**l**uluku* 'old man') or secondary stress (e.g. *balaka**rr**aba* 'block, stop from fighting').

Vocalic and Stress Environment		[l]	[ɭ]	[ʎ]
/a_a/	Before		4(1)	
	After	9(5)	8(2)	6(1)
/i_i/	Before			
	After	4(1)		
/u_u/	Before	1		
	After	10(4)	1	

Table 2a: Second data set – distribution of laterals (the number in brackets represents the number of different words that make up the token count)

Vocalic and Stress Environment		[ɹ]	[ɾ]
/a_a/	Before		
	After	8(5)	3(1)
/i_i/	Before		
	After		
/u_u/	Before		
	After	3(2)	1

Table 2b: Second data set – distribution of rhotics (the number in brackets represents the number of different words that make up the token count)

3.3. Measurements

Using the words segmented from the audio files, a Praat TextGrid was created to annotate each token. This study focused on liquids with respect to the immediately adjacent sounds, which were vowels in all cases; this was by chance in the case of the minimal pairs, and by design for the second study. Each segment of the vowel—liquid—vowel (VLV) sequence was marked at its onset and offset based on wideband spectrogram patterns and aligned waveforms. The overall intensity contour of each sound file was also calculated and a point tier was added to the TextGrid to mark the points of maximum intensity decrease and increase, as exemplified in Figure 1. The time and overall intensity at each point was recorded.

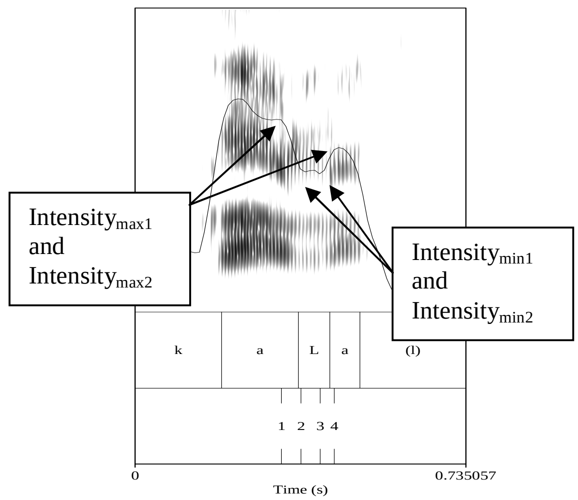

Figure 1: Example of intensity maximums and minimums across a VLV sequence

These annotations were made based on the measurements chosen to quantify some of the differences between the liquids. These measurements included the first three formant frequencies of the liquids as well as the absolute change and rate of change in overall intensity across the VLV sequence.

A common measure in the study of liquids is formant frequency (e.g. Stevens 1998; McDonald 2002), with most liquids displaying a unique formant structure. The mean frequencies of $F1$, $F2$ and $F3$ were calculated at the midpoint of the liquids, based on the onset and offset manually marked in the TextGrid. The midpoint was calculated from the formant averages over two windows (25msec either side of the midpoint, with a window length of 25msec).

The rate of intensity change measure was included to distinguish laterals from the central approximant [ɹ]. Laterals involve a rapid closure and release and an acoustic correlate of this is an abrupt intensity change across VLV sequences. In comparison, [ɹ] does not involve an abrupt contact and release, thus the intensity change across segments is more gradual. It was also anticipated that there would be a greater intensity change for [ɾ] due to the brief closure period. As there is even less constriction for vowel production, this results in a measurable change in intensity across a VLV sequence. In order to quantify this difference, the slope of maximum intensity decrease (3) and maximum intensity increase (4) during the VLV sequence was

Proceedings of the 11th Australian International Conference on Speech Science & Technology, ed. Paul Warren & Catherine I. Watson. ISBN 0 9581946 2 9
University of Auckland, New Zealand. December 6-8, 2006. Copyright, Australian Speech Science & Technology Association Inc.

Accepted after abstract only review

measured, in addition to the absolute intensity decrease (1) and increase (2).

$$\text{Intensity}_{\text{max1}} - \text{Intensity}_{\text{min1}} \quad (1)$$

$$\text{Intensity}_{\text{min2}} - \text{Intensity}_{\text{max2}} \quad (2)$$

$$\text{Intensity}_{\text{max1}} - \text{Intensity}_{\text{min1}} / \text{Time}_{\text{max1}} - \text{Time}_{\text{min1}} \quad (3)$$

$$\text{Intensity}_{\text{min2}} - \text{Intensity}_{\text{max2}} / \text{Time}_{\text{min2}} - \text{Time}_{\text{max2}} \quad (4)$$

The first data set was measured first and the results suggested that the location of the first intensity minimum (intensity$_{\text{min1}}$), in relation to the segment onset and offset, was potentially a distinguishing feature of the alveolar – postalveolar lateral contrast. This was quantified as a measure of intensity valley alignment (IVA) in the second data set. The IVA expresses as a percentage the location of intensity$_{\text{min1}}$ within the lateral segment and was calculated using the formula in (5).

$$(\text{time}_{\textit{intensity min1}} - \text{time}_{\textit{onset}}) / (\text{time}_{\textit{offset}} - \text{time}_{\textit{onset}}) * 100 \quad (5)$$

4. Results

4.1. Minimal Pairs

Formant frequency measures were successful in contrasting a number of the liquids. The contrast between [l] and [ɹ] involved a slightly lower *F*1 and *F*2 in the former and a clearly lower *F*3 in the latter. The lamino-palatal lateral [ʎ] was distinguished from [l] by a lower *F*1 and higher *F*2 and *F*3. Formant frequencies as measured at the midpoint of the segment revealed no difference between [l] and [ɭ]; however, the formant trajectories from the pre-lateral vowel through to the lateral were significantly different. Not only did [ɭ] induce a falling *F*3 and rising *F*2 in the pre-lateral vowel, *F*3 during the lateral was dynamic, in comparison to the stable *F*3 of [l], shown in Figure 2. To capture this difference between the *F*3 of [l] and [ɭ], two measurements were made for the *F*3 of [ɭ]: one at the onset when *F*3 was at its minimum and another just before the lateral offset when *F*3 was at its maximum.

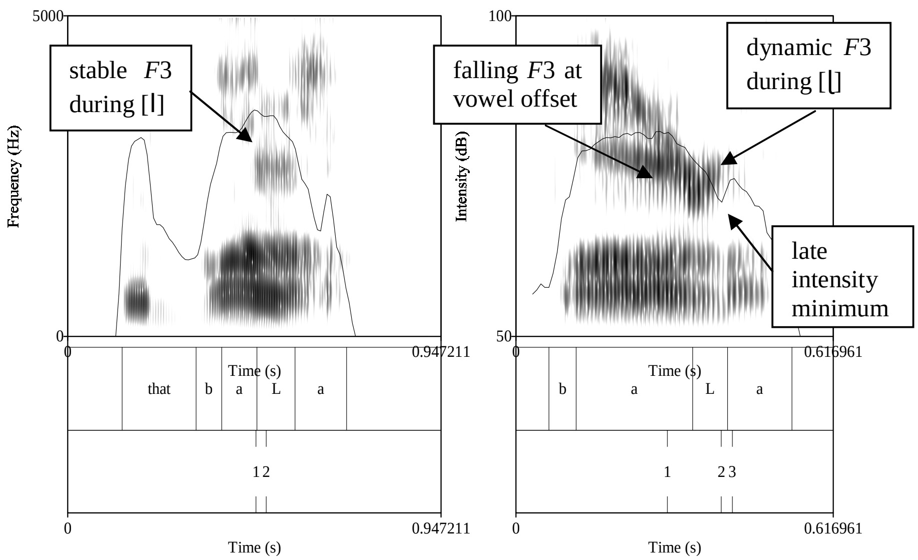

Figure 2: Spectrograms and intensity contours of *bala* (left) and *barla* (right)

As expected, the intensity measures distinguished [l] from [ɹ]; the increase and decrease was smaller for [ɹ]. There were also differences between the intensity of the laterals; [l] had smaller changes than [ɭ] and [ʎ]. An asymmetry was noted between the intensity decrease and increase of [l]; a greater decrease than increase was produced. This direction of asymmetry was unexpected given that greater changes at the lateral offset than release are usually reported (e.g. Stevens, 1998: 550).

4.2. Effects of vocalic and stress environments

The different vocalic environments had the following effects on the formant values of liquids:

- /a_a/ - raise *F*1, slightly raise *F*3
- /i_i/ - lower *F*1, raise *F*2
- /u_u/ - slightly lower *F*1, lower *F*2, lower *F*3

Proceedings of the 11th Australian International Conference on Speech Science & Technology, ed. Paul Warren & Catherine I. Watson. ISBN 0 9581946 2 9
University of Auckland, New Zealand. December 6-8, 2006.

Accepted after abstract only review

The vocalic environment produced no clear effect on the intensity measures, although the IVA values for [l] were generally higher and more variable in the /a_a/ environment.

While the vocalic environment had a clear effect on the formant frequencies, the stress environment did not appear to have a consistent effect on the liquids. This is most likely due to the small data set which had a limited number of contrasts for the stress variable.

4.3. Distinguishing features for the liquids

The measurements revealed a number of features which distinguished the liquids from one another. The overall means and standard deviations for the different measures are given in Tables 3 and 4.

The distinguishing features for the alveolar lateral [l] were: i) variable amount of *F*3 lowering, ii) stable formants throughout [l], iii) no distinct formant transitions, iv) low IVA, v) similar rates of intensity change and vi) greater absolute intensity increase than decrease.

In contrast to this, the postalveolar lateral [ɭ] distinguishing acoustic features were: i) *F*2 and *F*3 transitions from preceding vowel, ii) dynamic *F*3 throughout [ɭ], iii) high IVA, iv) greater rate of intensity decrease than increase and v) greater absolute intensity decrease than increase.

The distinguishing acoustic features for the lamino-palatal [ʎ] were: i) *F*1, *F*2 and *F*3 transitions from adjacent vowels, ii) stable formants throughout [ʎ], iii) greater rate of intensity increase than decrease and iv) similar absolute intensity changes.

The central approximant [ɹ] generally produced a dipping *F*3 which has been described in the literature as a distinguishing acoustic feature of this sound. The consistent acoustic features across the tokens were: i) dipping *F*3 during [ɹ], ii) low rate of intensity change and iii) similar absolute intensity changes.

Finally, the consistent acoustic features for [ɾ] were: i) slightly lowered *F*3 during [ɾ], ii) greater rate of intensity decrease than increase and iii) similar absolute rates of intensity change. Feature (i) is only based on the tokens found in the /a_a/ frame as these had attenuated formant structure during the closure period.

	n	*F*1 (Hz)	*F*2 (Hz)	*F*3 (Hz)	*F*3 (Hz) min – max
[l]	24	498	1299	2236	n.a.
		72	264	220	
[ɭ]	13	564	1391	n.a.	2289 – 2776
		26	203		111 – 190
[ʎ]	6	451	1939	2677	n.a.
		46	86	85	
[ɹ]	10	571	1321	2256	n.a.
		84	153	354	
[ɾ]	4	623	1412	2555	n.a.
		20	67	186	
		(*n*=3)	(*n*=3)	(*n*=3)	

Table 3: Overall formant means and standard deviations

	n	AID (dB)	RoID (dB/cs)	AII (dB)	RoII (dB/cs)	IVA (%)
[l]	24	2.98	0.84	4.3	0.85	21.0
		1.9	0.45	2.08	0.39	16.0
		(*n*=23)	(*n*=23)	(*n*=21)	(*n*=21)	(*n*=23)
[ɭ]	13	4.44	1.02	1.74	0.83	83.6
		2.32	0.4	1.13	0.35	8.0
				(*n*=11)	(*n*=11)	
[ʎ]	6	4.75	0.88	4.17	1.0	n.a.
		2.03	0.39	1.65	0.41	
[ɹ]	10	2.82	0.72	3.21	0.73	n.a.
		1.43	0.27	2.44	0.31	
		(*n*=7)	(*n*=7)	(*n*=6)	(*n*=6)	
[ɾ]	4	2.83	0.93	2.82	0.63	n.a.
		1.09	0.16	3.12	0.21	

Table 4: Overall intensity means and standard deviations

5. Discussion

These acoustic features enable distinctions to be made between the liquids. [l] contrasts with [ɭ] in terms of formant transitions, formant trajectories, IVA and the direction of asymmetry for intensity changes. [l] contrasts with [ʎ] in terms of formant transitions and formant values. The rates of intensity change were similar for [l] and [ʎ], although [l] tended to have a smaller absolute intensity decrease than [ʎ]. The contrast between [ɭ] and [ʎ] is in terms of *F*1 transition, lateral *F*3 trajectory and intensity pattern. [ʎ] also contrasts with the apical laterals by having formant transitions in the preceding <u>and</u> following vowels. This is in keeping with other research which has found that in a V1CV2 sequence there are important cues for apical place of articulation only in V1, but for laminal consonants there are cues in both V1 and V2 (Anderson 2001).

There was a clear perceptual and acoustic difference between [ɹ] and [ɾ]. The latter was obviously different in that contact was made by the articulators, resulting in a closure period and a greater rate of intensity change. Some similarities existed in the formant structure. In those cases where the formant structure was measurable during [ɾ], *F*3 was slightly lowered and there were also some tokens which included an extra concentration of acoustic energy across the VLV sequence. There was also a similar absolute change in intensity for both these sounds.

Based on these distinguishing acoustic features, it is evident that there are similarities between [ɭ] and [ɹ]. Both involve a falling *F*3 and some tokens produced

Proceedings of the 11th Australian International Conference on Speech Science & Technology, ed. Paul Warren & Catherine I. Watson. ISBN 0 9581946 2 9

Accepted after abstract only review

extra acoustic energy between *F*2 and *F*3. However these characteristics differ in terms of timing. For [ɹ], the falling *F*3 continues through the first half of the segment before it begins rising, whereas for [ɭ], the falling *F*3 is part of the transition of the preceding vowel; only raising (and no falling) occurs during [ɭ]. There was also a clear difference in terms of intensity change; [ɭ] had greater rates and also a greater absolute intensity decrease than [ɹ].

In terms of the debate over the phonemic status of the alveolar – postalveolar contrast, there is strong evidence for a phonemic double apical series among the Wanyi laterals, given the *bala* ~ *barla* minimal pair. The question to ask, then, is whether this contrast is maintained throughout the stops and nasals. In lieu of a systematic study of these series, which should be a key priority for future research, the implications of finding a place contrast in the Wanyi laterals can be considered in relation to contrasts found in other Australian languages.

Laterals can contrast at up to four places of articulation in languages with the maximal coronal contrasts of a double apical and laminal series, such as Pitta-Pitta (Dixon 1980: 143). Unlike the nasals, which always pattern with the stops in terms of place of articulation, the laterals can lack a contrast which is found in the stops and nasals. Guugu Yimidhirr contrasts apico-alveolar, lamino-dental and lamino-palatal in the stops and nasals, but only has a single lateral, /l/ (Dixon 1980: 143). However, there are no languages which make a contrast in the laterals not made in the stops and nasals. This suggests that an implicational hierarchy exists for distinctive feature contrasts in Australian languages; if a place feature is contrasted in the laterals, then it is also contrasted in the stops and nasals. However, if a place feature is contrasted in the stops and nasals, this does not imply that the feature will be contrasted in the laterals.

Returning to Wanyi, the evidence for an alveolar – postalveolar contrast in the laterals implies that there is also a contrast in the stops and nasals, and thus a phonemic double apical series. Such a contrast would also align Wanyi with neighbouring languages which all have double apical series; Yukulta (Tangkic), Wakaya, Indjilandji and Yanyuwa (Warluwarric), and Wambaya (West Barkly). Breen (2003) claimed that Garrwa only has a single apical series (in keeping with what he proposed for Wanyi), although earlier analyses of Garrwa proposed a double apical series (Furby 1974). Given the findings for Wanyi in this study, it would be worthwhile investigating the apical contrast in Garrwa.

6. Acknowledgements

This study formed part of my Honours thesis and I would like to thank my supervisors, John Ingram and Mary Laughren, for their guidance throughout the year.

7. References

Anderson, V.B. (2001). Giving Weight to Phonetic Principles: The Case of Place of Articulation in Western Arrernte. *Dissertation Abstracts International, A*, 61, 8, 3141A.

Boersma, P. & D. Weenink (2006). *Praat: doing phonetics by computer [computer program]*, Version 4.4.04. <www.praat.org>.

Breen, G. (2003). Wanyi and Garrwa comparative data. In N. Evans (Ed.), *The non-Pama-Nyungan languages of northern Australia: comparative studies of the continent's most linguistically complex region* (pp. 425-462). Canberra: Pacific Linguistics.

Dixon, R.M.W. (1980). *The Languages of Australia*, Sydney: Cambridge University Press.

Evans, N. (1995). Current issues in the phonology of Australian languages. In J.A. Goldsmith (Ed.), *The Handbook of Phonological Theory* (pp. 723-761). Cambridge MA: Blackwell Publishers.

Furby, C.E. (1974). Garrwa Phonology. In S.A. Wurm (Ed.) *Papers in Australian Linguistics No.7* (pp. 1-11). Canberra: Pacific Linguistics.

Ladefoged, P. (2003). *Phonetic Data Analysis: An Introduction to Fieldwork and Instrumental Techniques*, Malden MA: Blackwell Publishing.

Ladefoged, P. & I. Maddieson (1996). *The Sounds of the World's Languages*, Oxford: Blackwell Publishers.

Laughren, M. (2000 – 2005). *Wanyi spoken by Roy Seccin Kamarrangi in Queensland on 11-15 September 2000*, University of Queensland.

Lindau, M. (1985). The story of /r/. In V.A. Fromkin (Ed.), *Phonetic Linguistics: Essays in Honour of Peter Ladefoged* (pp. 157-168). Orlando: Academic Press, Inc.

McDonald, M. (2002). *A study of the Phonetics and Phonology of Yaraldi and Associated Dialects*, Munich: LINCOM EUROPA.

Narayanan, S.S., Byrd, D & A. Kaun (1999). Geometry, kinematics, and acoustics of Tamil liquid consonants. *Journal of the Acoustical Society of America*, 106, 1993-2007.

Nordlinger, R. (1998). *A Grammar of Wambaya, Northern Territory (Australia)*, Canberra: Pacific Linguistics Series C-140, Pacific Linguistics.

Osborne, C. (1966). A tentative description of the Wanji language. AIATSIS Unpublished MS.

Stevens, K. (1998). *Acoustic Phonetics*, Cambridge MA: MIT Press.

Stokes, B. (1975). The Wanyi Language - A Late Glimpse. ANU Unpublished MS.

Wiese, R. (2001). The phonology of /r/. In T.A. Hall (Ed.), *Distinctive Feature Theory* (pp. 335-368). Berlin: Mouton de Gruyter.