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Pre-stopping in Arabana*

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Pre-stopping is a widespread and usually non-contrastive phenomenon in Australian languages. Contrastive pre-stopping is rare and materials on it are limited. Based partly on original phonetic data, this paper provides evidence that Arabana, a language of northern South Australia, has contrastive pre-stopping of both laterals and nasals. Current analyses of pre-stopping, both contrastive and non-contrastive, model pre-stopped sequences as complex segments, and relate their diachrony to perceptual motivations favouring the enhancement in the discrimination of place oppositions. We provide evidence that pre-stopped sequences in Arabana are best analyzed as heterosyllabic clusters, and that their diachrony centrally involves perceptual motivations favouring the augmentation of phonologically strong constituents, specifically stressed syllables.

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In memoriam—Luise Hercus
This paper is dedicated to Luise Hercus, a great Australian linguist who died on 15 April 2018. She worked with Mick McLean *Irinjili* and other Wangkangurru and Arabana people over many years, documenting languages, places and songs. This was an important component of Luise's immense contribution to recording the languages and cultures of Australia. This paper developed from discussions with Luise at the 16th Australian Languages Workshop in March 2017. However, increasing ill health prevented her from contributing extensively to the team's research programme. We hope this paper satisfies Luise's unwavering commitment to research excellence.

Keywords: Arabana; Phonological Augmentation; Phonetics; Pre-stopping; Nasals; Laterals; Kaytetye; Complex Segment

Q3 1. Introduction

In this paper, we examine the phonetics and phonology of homorganic [Stop][Lateral] and [Stop][Nasal] sequences in Arabana. We use the term 'Arabana' to refer to the variety discussed in this paper, as the original data we present were provided by the fourth author Sydney Strangways, a first-language speaker of Arabana. Sydney is one of the last first-language speakers of this set of language varieties, although language revival is underway.[1] The Arabana variety is a member of a set of mutually intelligible language varieties traditionally spoken in northern South Australia (Figure 1). The overall set is most commonly termed 'Arabana-Wangkangurru' and there is a complex nomenclature classifying variation within Arabana-Wangkangurru (Hercus 1994: 6–8, 15–18).

Homorganic [Stop][Lateral] and [Stop][Nasal] sequences are widely attested in Australian languages. The earliest discussion we have found is Teichelmann and Schürmann's (1840: 3) recognition of an alternation between homorganic [Stop][Lateral] and [Lateral] in Kaurna. Strehlow (1942: 269–275) described 'sequences' or 'combinations' of stop + nasal in Arrernte. O'Grady *et al.* (1966: 58) described a nasally released set of stops and a laterally released set of stops in 'Wailpi' (Adnyamathanha) and some of its neighbours. Dixon (1970) appears to have been the first to use the term 'pre-stopped' of similar sequences in his analysis of Olkola. Hercus (1972) uses the term 'pre-stopped' in her discussion of laterals and nasals in Arabana and neighbouring languages. Subsequently, homorganic [Stop][Lateral/Nasal] sequences are generally termed 'pre-stopped lateral/nasal' in the Australianist literature (Dixon 2002: 597; Fletcher & Butcher 2014: 109–110). We follow this general usage and refer to these sequences with the terms 'pre-stopped' and 'pre-stopping'.

Despite their widespread occurrence, there are comparatively limited materials on the phonetics of pre-stopping (§3).[2] There is only one detailed examination of the phonological status of contrastive pre-stopping, for the Arandic language Kaytetye (Harvey *et al.* 2015). This analysis proposes a phonological analysis of pre-stopped sequences as complex segments: e.g. [tn] as /^{t}n/. This appears to be the default analysis adopted generally for contrastive pre-stopping (Dixon 2002: 597; Henderson 1998: 24–27; Koch 1997: 276–277).

The distribution of pre-stopping in Arabana differs significantly from that in Kaytetye, and other Arandic varieties (§5). Current analyses propose that pre-stopping is

[1] See http://www.mobilelanguageteam.com.au/languages/arabana (Mobile Language Team in conjunction with the Arabana Aboriginal Corporation), which presents material produced by Arabana people in conjunction with Greg Wilson.

[2] Strehlow (1942) gives a detailed perceptual account of the allophony of Arrernte stops and pre-stopped nasals, including the observation that Kukatja L2 speakers of Arrernte used sequences of vowel plus long nasal to substitute for pre-stopped nasals.

Figure 1 General map of Arabana-Wangkangurru country, drawn by V. Potezny (Hercus 1994: xiv)

Q7

not contrastive phonemically in Arabana (Hercus 1994: 43). We provide evidence that pre-stopping is indeed not phonemically contrastive in Arabana. Rather, we provide both phonetic and phonological evidence that Arabana pre-stopped sequences are contrastive as clusters: e.g. [tn] as /t/ + /n/. As such, contrastive pre-stopped sequences do not have a uniform analysis in Australian languages.

We consider the roles of perception and production in the realization of pre-stopping. Butcher (2006: 197–199) proposes that pre-stopping arises as a non-contrastive by-product when there is a high ranking for the maintenance of transition cues into nasals, because this maintenance assists in the discrimination of place oppositions. Round (2014: 89–91) agrees that pre-stopping is perceptually advantageous for nasals. However, he proposes that the origin of pre-stopping lies in articulatory rather than perceptual factors, and that pre-stopping is most likely to arise in segments of long duration and in segments with places of articulation whose oral closure durations are short. We consider articulatory factors further in §5.3. In terms of perception, we propose that a quite different factor, the augmentation of phonologically strong positions, can select pre-stopping as a target and that this has played a central role in the development of pre-stopping in Arabana. We consider the relations between targeted and non-targeted productions of pre-stopping and the contrastive vs non-contrastive phonological opposition.

We begin by presenting the synchronic distribution of pre-stopping in Arabana (§2). Subsequently, we examine the phonetics of pre-stopping in other Australian languages (§3), as a comparative baseline for the evaluation of original data on the phonetics of pre-stopping in Arabana, presented in §4. We then evaluate phonological analyses of Arabana pre-stopping in §5, and examine some of the factors which appear to have played a central role in the diachrony of pre-stopping in §6.

2. Synchronic Distribution of Pre-stopping in Arabana

This description of the synchronic distribution of pre-stopping in Arabana is based on materials in Hercus (1994) and on a lexical database with approximately 2,000 headwords.[3] The pre-stopped sequences attested phonetically in Arabana are highlighted in Table 1, which otherwise presents the inventory of phonemically contrastive segments in an IPA orthography (Hercus 1994: 26). The distribution of these pre-stopped sequences is complex and is conditioned by a number of independent factors: emphasis, metrical structure, morphosyntactic structure, part-of-speech categorization, phonotactic structure, place oppositions (Hercus 1994: 37–42).

The opposition between anterior and posterior places of articulation is a key factor conditioning the frequency of pre-stopping. Pre-stopped sequences in the posterior places of articulation have a marginal status. The velar [kŋ] is attested only in one place name *Yatalknga* [ˈjatalkŋa] (Hercus 1994: 40).[4] The retroflex and palatal sequences appear as alternates to plain lateral and nasal realizations, when words

[3] An older, unprocessed version of the lexical database is openly accessible through the AIATSIS catalogue, http://catalogue.aiatsis.gov.au/ (call number: AILEC 0238).

[4] This place name is distinctive in two further ways: (i) it is the only autochthonous lexeme with a pre-stopped sequence not in post-tonic position; (ii) it is the only example of a pre-stopped sequence appearing in a cluster (§5.1). Hercus (1994: 40) notes further that *Yatalknga* is a goanna ritual site, and that the goanna song cycle is almost entirely in Aranda. Arandic varieties permit sequences such as /lkŋ/ (Henderson 1998: 22).

Table 1 Arabana consonant inventory in IPA

	Anterior			Posterior		
	Labial	Dental	Alveolar	Retroflex	Palatal	Velar
Stop	*p*	t̪	t	ʈ	c	k
Nasal	m	n̪	n	ɳ	ɲ	ŋ
Pre-stopped nasal[a]	**pm**	**t̪n̪**	**tn**	**?ʈ**	**?cɲ**	**kŋ**
Lateral		l̪	l	ɭ	ʎ	
Pre-stopped lateral[a]	–	**t̪l̪**	**tl**	**ʈɭ**	**cʎ**	–
Tap			ɾ			
Trill			r			
Continuant	w			ɻ	j	

Notes: [a]Phonetically attested pre-stopped sequences. [b]The uncertainty in relation to retroflex nasal pre-stopping is indicated by the question mark; Hercus (1994: 39–40) provides examples of pre-stopping for the palatal lateral and nasal and for the retroflex lateral, but not for the retroflex nasal. Hercus (1972: 295–298) indicates that she had not found pre-stopping of retroflex nasals, that there were no clear examples of pre-stopping of palatal nasals, and that pre-stopped retroflex and palatal laterals were rare.

are pronounced with emphasis (Hercus 1994: 39–40). As the posterior pre-stopped sequences have a marginal status in Arabana, we do not consider them further.

By contrast, the anterior sequences are attested with reasonable frequency. Consequently, we focus on the phonetic and phonological analysis of the anterior sequences. The standard Arabana orthography includes representation of these anterior sequences, and therefore we generally present materials in the standard orthography, which is set out in Table 2.

The other factors—metrical structure, morphosyntactic structure, part-of-speech categorization, phonotactic structure—show complex interactions with one another. As a preliminary to examining these interactions, it is useful to present an overview of the principal characteristics of morpheme and word structures in Arabana, listed below in example (1), all of which are consistent with general patterns for Australian languages (Baker 2014).

Table 2 Arabana consonant inventory in standard orthography

	Anterior			Posterior		
	Labial	Dental	Alveolar	Retroflex	Palatal	Velar **Q8**
Stop	*p*	*th*	*t*	*rt*	*ty*	*k*
Nasal	*m*	*nh*	*n*	*rn*	*ny*	*ng*
Pre-stopped nasal	***bm***	***dnh***	***dn***			
Lateral		*lh*	*l*	*rl*	*ly*	
Pre-stopped lateral[a]		***dlh***	***dl***			
Tap			*r*			
Trill			*rr*			
Continuant	*w*			*R*	*y*	

Note: [a]Phonetically attested pre-stopped sequences.

(1) (a) Arabana is a suffixing language, and morphology is largely agglutinative[5]
(b) Lexical morphemes are minimally disyllabic
(c) There is no minimum size constraint on grammatical morphemes
(d) Footing is trochaic
(e) Feet are aligned with the left edges of polysyllabic morphemes
(f) The head foot is the left-most foot

2.1. Pre-stopping in Simplex Lexical Words

We begin by considering the distribution of pre-stopping in simplex lexical words, which we define as words based on a lexical root, involving only one foot: i.e. words consisting of solely a lexical root, or just a lexical root and monosyllabic suffixes. The most prominent constraint in this environment is metrical. Pre-stopped sequences are essentially restricted to the post-tonic position (Hercus 1994: 37). Given the factors in example (1), the first vowel is the tonic vowel (Hercus 1994: 47). Consequently, there are lexical roots with plain laterals and nasals in later positions, *kunti**li*** 'crossways', *murri**lh**a* 'drought', *kuru**n**a* 'mind', *ngarka**ni*** 'moon', but not lexical roots with pre-stopping in later positions: e.g. **murri**dlh**a*, **kuru**dn**a*.

Apart from this metrical constraint, there are phonotactic constraints which relate to the nature of the initial segment. If the initial segment is a nasal, then a pre-stopped nasal cannot appear in post-tonic position, only a plain nasal can appear in this position: e.g. *mu**nh**a* 'chest', **mu**dnh**a*. Thus, there is a constraint *NVSN. Otherwise, if the initial segment is a consonant, there is a strong preference for pre-stopped laterals and nasals in post-tonic position, with plain laterals and nasals being uncommon.

In Arabana, as in most Australian languages, unanalyzable lexical roots are rarely more than three syllables in length. Roots of four or more syllables are usually historically analyzable, and often have somewhat variable degrees of synchronic analyzability. To avoid potential analyzability issues, we extracted two and three syllable consonant-initial roots from the lexical database and examined the distribution of plain and pre-stopped laterals and nasals.

(2)

#CV[Stop][Lateral/Nasal] …	97	91%
#CV[Lateral/Nasal] …	10	9%

While there is a very strong preference for pre-stopping in post-tonic position, the plain laterals and nasals cannot be analyzed as an outlier phenomenon. There is a subminimal pair, contrasting the plain and pre-stopped dental nasals, which is set out in example (3).[6]

(3)

*ya**nh**i-rnda*	'speak-PRES'	(Hercus 1994: 82)
*wa**dnh**i-rnda*	'cook-PRES'	(Hercus 1994: 84)

[5] Exceptionally, some reciprocal terms involve a prefix *pura-* (Hercus 1994: 14).
[6] Verbs normally occur with tense suffixes (except in the Dramatic Past).

Hercus (1994: 40) notes that for some words with an initial dental or palatal consonant (i.e. laminal), there is variation between [dn] and [n] in realizations in the post-tonic position.[7]

(4)	'youth'	*yadningka*	[jadniŋka] ~ [janiŋka]
	'leave'	*thadna-*	[t̪adna-] ~ [t̪ana-]

The situation when the initial segment is a vowel is to a large degree the converse of that where the initial segment is a consonant. In this situation, there are no examples of consistently pre-stopped laterals. Hercus (1994: 39) reports two lexemes where plain and pre-stopped lateral realizations vary.

(5)	'woman'	*ulyurla*	[uʎuɭa] ~ [ucʎuɭa]
	'paternal grandfather'	*idlhili* ~ *ilyirli*	[it̪l̪ili] ~ [iʎiɭi]

There are only 11 lexical roots with the form #V(Stop)[Nasal] … in the lexical database, with the patterns set out in example (6).

(6)	#a[Nasal]	4
	#a[Nasal] ~ #a[Stop][Nasal]	1
	#i[Nasal]	3
	#i[Stop][Nasal]	3

There does not appear to be a particularly clear pattern for roots with an initial vowel, when [Nasal] appears in post-tonic position. The overall patterns for simplex words are summarized in Table 3.

2.2. Pre-stopping in Grammatical Words

We use the term 'grammatical word' to refer to words with a grammatical root. The exact division between 'lexical' and 'grammatical' is subject to much debate. We do not contribute to this debate here, but use the terms with a broad descriptive sense. The two largest classes of grammatical words are personal pronouns and demonstratives. These show complex, irregular paradigms in Arabana, and the plausibility of synchronic analysis into root + suffix combinations varies considerably (Hercus 1994: 106–129). Regardless of their potential internal structure, pre-stopping is absent, even though the form otherwise satisfies the conditions for pre-stopping in simplex words.

(7)	'3.DUAL'	*pula*	**pudla*
	'that. ACC'	*kanha*	**kadnha*
	'yon.ERG/ABL'	*waluru*	**wadluru*

Depending on how the division between 'lexical' and 'grammatical' is drawn, there is variation in the appearance of pre-stopping in other grammatical words. The high frequency Negator *padni* 'no, none' shows pre-stopping, but *malaru* 'however' and *pinha* 'already' do not.

[7] Hercus includes *yanhi* 'speak, talk' in this discussion, reporting a variation between pre-stopped and plain alveolar realizations: [jadni-] ~ [jani]. However, 'speak, talk' is extensively attested in the grammar and listed in the lexicon as *yanhi* with a plain dental nasal. It is not otherwise attested as an alveolar or with pre-stopping.

Table 3 Distribution of pre-stopping in simplex lexical words

	[Lateral]	[Stop][Lateral]	[Nasal]	[Stop][Nasal]
#C[+ Nasal]V	Rare	Standard	Standard	Not attested
#C[–Nasal]V	Minority	Standard	Minority	Standard
#V	Standard	Minority	No clear pattern	No clear pattern

2.3. Pre-stopping in Complex Words

We define complex words as words involving two or more feet. There is considerable variation in the appearance of pre-stopping in complex words. As discussed in example (1), all lexical roots are minimally disyllabic and all polysyllabic morphemes constitute independent metrical domains. Consequently, there are three principal classes of complex words, as set out in example (8).

(8) (a) Words involving polysyllabic suffixes
    (b) Compounds
    (c) Reduplications

2.3.1. Polysyllabic suffixes

In all words involving polysyllabic suffixes, the distribution of pre-stopping for the initial lexical root matches to the distribution of pre-stopping for the root in a simplex word; i.e. lexical roots show the same distribution of pre-stopping regardless of type of suffixation. There are three polysyllabic suffixes which do or could potentially show pre-stopping: Dual, Possessive, Privative. The Privative suffix is *-padni* with consistent pre-stopping in Arabana (Hercus 1994: 94–95). The Privative suffix evidently relates to the free Negator *padni* 'no, none'. The realization of the other two suffixes appears to have varied dialectally, with the Wangkatyaka dialect showing pre-stopped variants, but the other dialects showing plain variants (Hercus 1994: 41).

(9)

	Wangkatyaka	Other varieties
'Possessive'	*-kudnha*	*-kunha*
'Dual'	*-pudla*	*-pula*

Given that polysyllabic suffixes constitute independent feet, it appears that the metrical conditioning may have differed in Wangkatyaka. Rather than just the primary tonic metrical head, any metrical head may have licensed following pre-stopping. The variation in the licensing capacities of metrical heads appears relevant to the distribution of pre-stopping in the other two major classes of complex words, compounds and reduplications.

2.3.2. Compounds

In Arabana, a range of semantic structures can be associated with a configurational structure involving two nominal roots. One of these semantic structures is inalienable possession meanings, in which case the configuration has open, endocentric semantics (Hercus 1994: 74).

(10)	(a)	*madla*	*wimpa*	*madla-wimpa*	(b)	*ulyurla*	*thidna*	*ulyurla-thidna*
		'dog'	'track'	'dog's track'		'woman'	'foot'	'woman's foot'

When the configuration has this endocentric interpretation, it appears that the distribution of pre-stopping in the roots matches to that in their independent occurrence, and each metrical head is functioning as a licensor of pre-stopping. With exocentric interpretations, pre-stopping in the first root matches to that found in independent occurrences, but pre-stopping in the second root may or may not match to that found in independent occurrences (Hercus 1994: 41).

(11)	*yarri*	*pudlu*	*yarri-pu**dl**u* ~ *yarri-pu**l**u*
	'ear'	'dull'	'deaf'

With exocentric interpretations, the primary metrical head is a consistent licensor, whereas secondary metrical heads are not consistent licensors.

2.3.3. *Reduplications*

With reduplications, the most frequent pattern appears to be that neither constituent shows pre-stopping, even though the root shows pre-stopping when occurring independently (Hercus 1994: 41–42). However, there are variations where either the first constituent or both constituents show pre-stopping.

(12)	*madla*	*ma**l**a-mala* ~ *ma**dl**a-mala*
	'dog'	'doggie'

(13) *ku**dnh**a-ku**dnh**a* ~ *ku**nh**a-ku**nh**a* '(bright) green'

Hercus (1994: 42) notes that 'When a reduplicated word is not felt to be a single unit, that is when there is repetition rather than reduplication, pre-stopping occurs as in the single word'.

(14)	*padni*	*padni*	*yadni*	*yadni*
	not	not	soon	soon
	'Definitely not!'		'Just a minute!'	

2.3.4. *Longer lexical roots*

The variable distribution of pre-stopping in complex words is matched by a tendency for the variable distribution of pre-stopping in some roots of four or more syllables (Hercus 1994: 40–41).

(15)	*yu**m**uwara*		'Milky Way'
	*Pa**l**aringu*	*Pa**dl**aringu*	'place name' (Hercus 1994: 41)
		*ngu**dl**ukanta*	'desert kangaroo rat'

Overall therefore, as Hercus (1994: 43) observes 'the rules governing pre-stopping are complex and there are a number of exceptions'. Generally, the exceptions to the rules cannot be analyzed as outliers. Some of the rules lack evident synchronic motivation.

(16) (a) V-initial disfavours pre-stopping of laterals, whereas C-initial favours pre-stopping of laterals
(b) An initial laminal favours variation between plain and pre-stopped realizations of a post-tonic alveolar nasal
(c) Absence of pre-stopping in most grammatical words

2.4. Pre-stopping in Non-native and Loan Words

One important factor in considering the synchronic status of distributional patterns is the treatment of non-native items and loans. If the distribution of pre-stopped and plain realizations in these classes is altered to match to the distribution in the native Arabana vocabulary, then this would be evidence that there were synchronically active constraints governing the comparative distribution of these realizations.

The principal class of overtly non-native items are place names and personal names whose attachments are to areas associated with Indigenous Australian language varieties other than Arabana. These names may involve distributions of plain and pre-stopped segments which depart from Arabana patterns. These departures are not remodelled to conform to Arabana patterns.

(17)	***Idny**untura*	'Kingfisher Spring'	pre-stopped palatal
	*Ingku**dn**a*	'Horseshoe Bend'	pre-stopping in non-tonic position

Both these place names are in territory associated with Lower Southern Aranda. The central role of land–language associations in Aboriginal sociality is probably an important factor impeding any remodelling in this situation.

Aside from these names, there are two principal classes of loans, those from Arandic and those from English. Arandic loans involving pre-stopping are illustrated in example (18).

(18)	*abmuna* ~ *amuna*	'red mulga'
	idnapa	'echidna'
	intikubma	'mountain devil' (lizard sp)

In Arandic varieties, approximately 75% of words are vowel-initial (Breen & Pensalfini 1999: 2). Consequently, Arandic loans are most likely to be vowel-initial. As discussed in this section, pre-stopping is rare in vowel-initial words in Arabana. Consequently, conversion of pre-stopping to plain equivalents is predicted. This has happened with 'red mulga', which has two lexical representations. However, it has not happened with 'echidna' which appears to have gained pre-stopping, as Hercus (1994: 39) compares it with Lower Southern Arrernte *inapa*. The 'mountain devil' term *intikubma* shows a different irregularity, pre-stopping in non-tonic position. Hercus (1994: 42) notes that these erstwhile loans are largely nativized.

The situation with English loans is somewhat different, because English phonotactics depart from those of Arabana in a number of ways, as summarized in example (19).

(19)

Arabana	English
No consonant-final morphemes	Many consonant-final morphemes
No apical-initial roots	Many apical-initial roots
No onset clusters	Many onset clusters

In any environment involving loans, there are two targets which can be in opposition: faithfulness to the source phonotactics and adaptation to the phonotactic patterns of the recipient language. The greater the exposure to the source language, the more likely it is that loans will show faithfulness to the source at the expense of adaptation to recipient phonotactic patterns. For first-language Arabana speakers, exposure to English increased continuously from initial contacts. Therefore, it may be predicted that later loans will show lesser adaptation to Arabana phonotactics than earlier loans. There is no detailed chronology of loans into Arabana. Forms recorded as loans in Hercus (1994) are listed in example (20).[8] All show some adaptation to Arabana phonotactics.

(20)

apikana	'Afghan'	*apurlu*	'apple'	*ipi*, *ipi-ipi*	'sheep'
kapula	'hobble'	*mayutha*	'master'	*mapu*	'mob'
nhikithi	'naked'	*padla*	'bottle'	*pilikana*	'billycan'
preta	'bread'	*pu(d)luka*	'bullock'	*putji-putji*	'cat'
rapiti	'rabbit'	*thamu*	'dam'	*tyampithi*	'jam tin'
'*waljpala* ~ *wadlupara*'		'white person'			

It may be observed that the constraints against consonant-final morphemes, and against apical-initial roots are enforced in the forms in example (20). By contrast, the constraint against onset clusters is not, at least for *preta* 'bread'. However, this form also shows an unadapted vowel /e/, and as such may be a later loan. The treatment of pre-stopping is variable, and is summarized in example (21).

(21)

	Adapted	Unadapted
'billycan'		*pilikana*
'bullock'	***pudluka***	*puluka*
'dam'		*thamu*
'white person'	***wadlupara***	

Two loans, *pilikana* 'billycan' and *thamu* 'dam', do not show adaptation, one loan *wadlupara* 'white person' shows adaptation, and one loan 'bullock' appears in both adapted and unadapted variants, *pudluka* and *puluka*. The 'bottle' loan *padla* cannot be evaluated for adaptation as the English source effectively involves a pre-stopped alveolar lateral. As such, it is not possible to determine whether the Arabana form reflects faithfulness to the English source or adaptation to Arabana preferences or both.

[8] The form *wadlupara* 'white person' is not listed in Hercus (1994). It is recorded on Arabana Tape 833 and was provided by Mona Merrick. Arabana speakers almost certainly used a wide range of approximations to [waitfɛlə], depending on the comparative weighting of three factors: (i) approximation to Arabana; (ii) approximation to English; (iii) emergence of unmarked structures in an inter-language environment. The *wadlupara* form involves emergence of unmarked CV syllable structure. The motivations for the approximation of /t/ as /dl/ and /l/ as /r/ require further investigation, but we note that in other languages the 't' is realized as /ʎ/ Warlpiri: *walypali*.

Overall therefore, the patterning of loans and non-native items clearly differentiates the treatment of the constraints against consonant-final morphemes and apical-initial roots from the treatment of the distributional patterns of pre-stopping. Analysis of the constraints against morphemes and apical-initial roots as synchronically active phonological constraints is supported. This is not supported for the distributional patterns of pre-stopping. The key post-tonic position shows variable and not fully consistent adaptation of loans. We suggest that this variable adaptation relates to the quantitative predominance, but not full predictability, of pre-stopping in post-tonic position in the native Arabana lexicon. A tendency to adapt towards quantitatively dominant patterns is pervasive in language, and it is to be expected that loans will conform to this tendency.

Given that the distribution of pre-stopping is not fully predictable, as indeed the subminimal pair in example (3) demonstrates, the prima facie analysis is that pre-stopping is a contrastive phenomenon, but one which shows a high degree of neutralization and of predictability. However, evidence from distributional patterns is not the sole parameter of relevance in phonological modelling. Patterns of phonetic realization are also a major analytical parameter.

3. Phonetics of Pre-stopping in Other Australian Languages

Across Australian languages there appear to be significant differences in phonetic realization between contrastive and non-contrastive pre-stopped sequences. In example (22), we summarize research materials on pre-stopping in three other Australian languages.

(22) (a) Contrastive pre-stopping of nasals and non-contrastive pre-stopping of laterals in Kaytetye (Harvey *et al.* 2015)
(b) Non-contrastive pre-stopping of nasals in Gupapuyngu (Butcher & Loakes 2008)
(c) Non-contrastive pre-stopping of laterals in Warlpiri (Loakes *et al.* 2008)

Among the languages in this database, the duration of the stop component in contrastive pre-stopping (Kaytetye nasals) is substantially longer than in non-contrastive pre-stopping (Kaytetye laterals, Gupapuyngu nasals, Warlpiri laterals), as set out in Table 4.

Table 4 Duration of pre-stopping in milliseconds

	Contrastive				Non-contrastive			
Labial					pm	17		
Alveolar	tn[a]	64	tl	21	tn	17	tl	29
Dental	t̪n̪	75	t̪l̪	37	t̪n̪	17		
Retroflex	ʈɳ	58	ʈɭ	27	ʈɳ	21	ʈɭ	16
Palatal	cɲ	49	cʎ	29	cɲ	20	cʎ	21
	Kaytetye				Gupapuyngu		Warlpiri	

Note: [a]Harvey *et al.* (2015) do not provide duration data by individual place. The Kaytetye figures in Tables 4 and 5 are calculated from the database for Harvey *et al.* (2015).

Table 5 Non-contrastive pre-stopping: percentage of pre-stopped realizations

	Kaytetye (laterals)		Gupapuyngu (nasals)		Warlpiri (laterals)	
Labial	n/a	n/a	pm	19%	n/a	n/a
Alveolar	tl	53%	tn	38%	tl	34%
Dental	t̪l̪	42%	t̪n̪	47%	n/a	n/a
Retroflex	ʈɭ	64%	ʈɳ	26%	ʈɭ	17%
Palatal	cʎ	51%	cɲ	12%	cʎ	17%

The consistency of contrastive pre-stopping also differs significantly from that of non-contrastive pre-stopping. Harvey *et al.* (2015: 242) report that in their Kaytetye data, 97.1% of pre-stopped nasal tokens were realized with initial stopping, and 97.5% of plain nasal tokens were realized without initial stopping. This is an essentially bimodal distribution of phonetic realizations matching to the phonological contrast of plain vs pre-stopped nasals. With non-contrastive pre-stopping, the consistency of pre-stopping varies significantly, as shown in Table 5.

In sum, if Arabana pre-stopping is contrastive, then we predict longer duration and greater consistency, so that the figures for Arabana should resemble the figures for the Kaytetye nasals. If Arabana pre-stopping is non-contrastive, then we predict shorter duration and less consistency, so that the figures for Arabana should be more like those for Kaytetye laterals, Gupapuyngu nasals and Warlpiri laterals. To date, there has been no quantitative research on the phonetics of pre-stopping in Arabana. To address this lacuna, we undertook two production studies of pre-stopping in Arabana.

4. Phonetics of Pre-stopping in Arabana

4.1. Stimuli

We searched the Arabana lexicon for headwords with anterior laterals and nasals, both plain and pre-stopped, in post-tonic position where the adjacent vowels were identical: i.e. $\#(C)V_1\_V_2(CV)+\#$, $V_1 = V_2$ (e.g. *kadnha* [ˈkad̪n̪a] 'money', *madla* [ˈmadla] 'dog'). We shortlisted headwords based on their ease-of-picturability and then trialled photos and illustrations for each headword. To prepare the visual elicitation materials, we first grouped headwords according to intervocalic environment (e.g. a_a, u_u), and then randomized the order of headwords within the group, and assigned each headword a unique identifier (e.g. B05T5 for *kadnha*). For each group, we created PDF slideshows where each slide contained a single image illustrating the headword and also its identifier code, as shown in Figure 2. For each slideshow, we also produced a runsheet containing a table of the headwords, their identifiers and the English definition. All elicited headwords and associated metadata are provided in Appendix A.

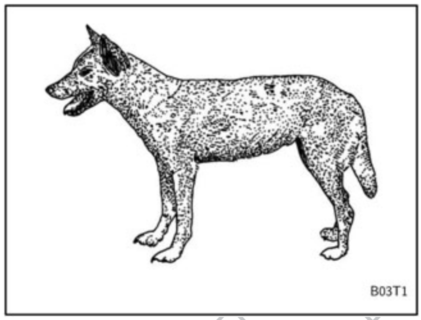

Figure 2 Example elicitation materials for two Arabana words, *kadnha* 'money' (left) and *madla* 'dog' (right)

4.2. Datasets

The analysis reported here is based on three datasets. Datasets 1 and 3 are materials recorded from author Sydney Strangways, an 87-year-old first-language speaker of Arabana, and were based on the stimuli discussed in §4.1. Dataset 1 was recorded in July 2017, but the materials recorded did not permit evaluation of place-of-articulation as a factor (§4.4). Dataset 3 was recorded in April 2018 to address this issue (§4.5). Dataset 2 is audio data from another first-language speaker of Arabana, now deceased. These data were not collected under experimental conditions.

4.2.1. Dataset 1

Author Sydney Strangways was recorded by author Margaret Carew across four separate sessions in July 2017. The recording venue was an office at the Desert Peoples Centre campus of Batchelor Institute in Alice Springs, a quiet location out of town. Background noise was minimal due to this location, though there was the occasional intrusion of office conversations and ambient bird sound can be heard in some of the recordings. A Tascam DR-100 audio recorder was used, with a Rode NT4 stereo microphone. The sample rate was set at 48 kHz with a bit depth at 24 bits per sample.

Prior to a recording session, Strangways and Carew reviewed the runsheet, with Sydney accepting some of the words and rejecting a number. Rejections were mostly on the basis of incorrect language affiliation, with Sydney identifying a number of words as Wangkangurru, and several as Diyari. He proposed correct Arabana replacement words for most of these items, matching these to the English meanings provided. In some cases, Sydney corrected the word to make it conform to correct Arabana. For example, the target word corresponding to stimulus B31T2 was provided as *malka-marnda* 'stripy'. Sydney rejected this in favour of the reduplicated form *malka-malka*, still meaning 'stripy', and suggested that the former must be a Wangkangurru word. Throughout these discussions Sydney made a number of such substitutions and additions, and also commented on meaning, clarified definitions, discussed semantic nuances and in some cases provided various inflected forms. The result of these discussions was a revised list of target words that closely matched the items in the runsheet (of 137 words: 30 amendments, five additions), give or take several that were rejected and had no obvious substitute.

Once the review was complete, Sydney was recorded producing a number of tokens in response to the visual stimuli (range: 4–8 tokens, median: 6 tokens). Audio from the recording sessions were then marked up by Carew in ELAN (ELAN 2018), annotating for the headword identifier, along with replacement and key commentary provided by Sydney. Information on all headwords elicited as expected, modified or substituted is also provided in Appendix A.

4.2.2. Dataset 2

We obtained audio materials which were originally recorded to accompany a set of Arabana teaching materials already in print (Hercus & Wilson 2004).[9] In order to provide comparison data with Dataset 1, we searched for the same orthographic sequences of interest within the obtained audio and retained only data from another comparable first-language male speaker of Arabana, Laurie Stuart. As the audio was produced for pedagogical purposes, however, the prosodic environment of the data varied from token to token.

4.2.3. Dataset 3

Following the analyses of Datasets 1 and 2, we collected additional data to shed light on place of articulation differences, which could not be addressed due to unbalanced token counts in Datasets 1 and 2 (§4.4). The same speaker of Dataset 1, author Sydney Strangways, was recorded by author Clara Stockigt in April 2018 across six separate sessions (one familiarization + five test sessions) in quiet locations. Unlike for Dataset 1, we sought only one type, #aCa(CV+)#, per condition for the 13 conditions-of-interest, which are displayed in Table 6 (cf. Appendix A for Dataset 1).[10] To yield sufficient tokens per condition for our analyses, each type was elicited twice within each session, with each elicitation prompting 5–6 tokens (i.e. 10–12 tokens per session; 50–60 tokens across sessions per type/condition). The order of elicitations was randomized across the six sessions. Recordings were made with a Zoom H5 recorder using its internal microphone. All other details regarding stimulus preparation, recording and annotation were identical between Dataset 1 and Dataset 3.

[9] We thank Greg Wilson for discussion and provision of this material.

[10] As discussed in §4.1, stimuli were limited to actual Arabana word forms. It was only in the a_a environment that sufficient word forms could be found to test all 13 conditions-of-interest. This was not possible for either the i_i or u_u environments.

Table 6 Arabana types elicited for Dataset 3 (speaker Sydney Strangways)

		Labial	Dental	Alveolar
Lateral	Plain	–	*alhakiya* we two, father + child	*alantha* we two, mother + child
	Pre-stopped	–	*ngadlha* cheek	*madla* dog
Nasal	Plain	*mamarnda* to take away	*anhaku* I don't know	*anari* this way, towards us
	Pre-stopped	*wabmarri* plain, plateau	*kadnha* stone, rock	*wadna* yam-stick
Oral stop		*waparnda* to hunt/seek	*katharungka* white cockatoo	*kata* head louse

4.3. Annotation Procedure

For each token in all three datasets, we annotated the first and second vowels and all intervening consonants: i.e. V_1, C_i, V_2 in $\#(C)V_1C_i{+}V_2(CV){+}\#$. We examined the waveform and spectrograms in Praat (Boersma & Weenink 2019). The offset of V_1 was determined by the reduction in waveform amplitude and loss of formant structure associated with the closure of an oral stop, as illustrated at landmark (A) in Figure 3. The offset of the closure, and onset of nasals and laterals, was determined by the increase in waveform regularity and presence of high-frequency spectral energy relative to the stop closures, as shown in Figure 3, landmark (B); bursts, if present, were identified through turbulence in the waveform, as shown in Figure 3, landmark (C). The offset of the sonorant, and onset of V_2, was determined by the increase in waveform complexity and appearance of formant structure, as shown in Figure 3, landmark (D).

We conducted inter-annotator reliability measures on 16% (29/184 tokens) of the pre-stopping data in Dataset 1 by having a second annotator independently produce a set of annotations using the same criteria. The mean difference between annotators for closure durations was found to be 6.00 ms (*SD* = 4.45 ms, *max* = 19.9 ms). For sonorant durations, the between-annotator mean difference was found to be 9.17 ms (*SD* = 7.08 ms, *max* = 25.4 ms). We found these aggregate margins of error to be acceptable as they fell within the range of two glottal pulses of the participant's voice (*M* = 6.69 ms, *SD* = 1.2 ms; 2*M* = 13.38 ms).

Similarly, for Dataset 3, a second person independently produced annotations for 10% (54/551 tokens) of the pre-stopping data within the dataset. For closure durations, the mean difference was found to be 9.84 ms (*SD* = 8.35 ms, *max* = 31.01 ms). For sonorant durations, the mean difference was found to be 13.07 ms (*SD* = 9.32 ms, *max* = 33.78 ms).

4.4. Results for Datasets 1 and 2

Duration is a potentially significant factor in the phonological analysis of phonetic sequences (Trubetzkoy 1969: 58). If a phonetic sequence is not significantly different

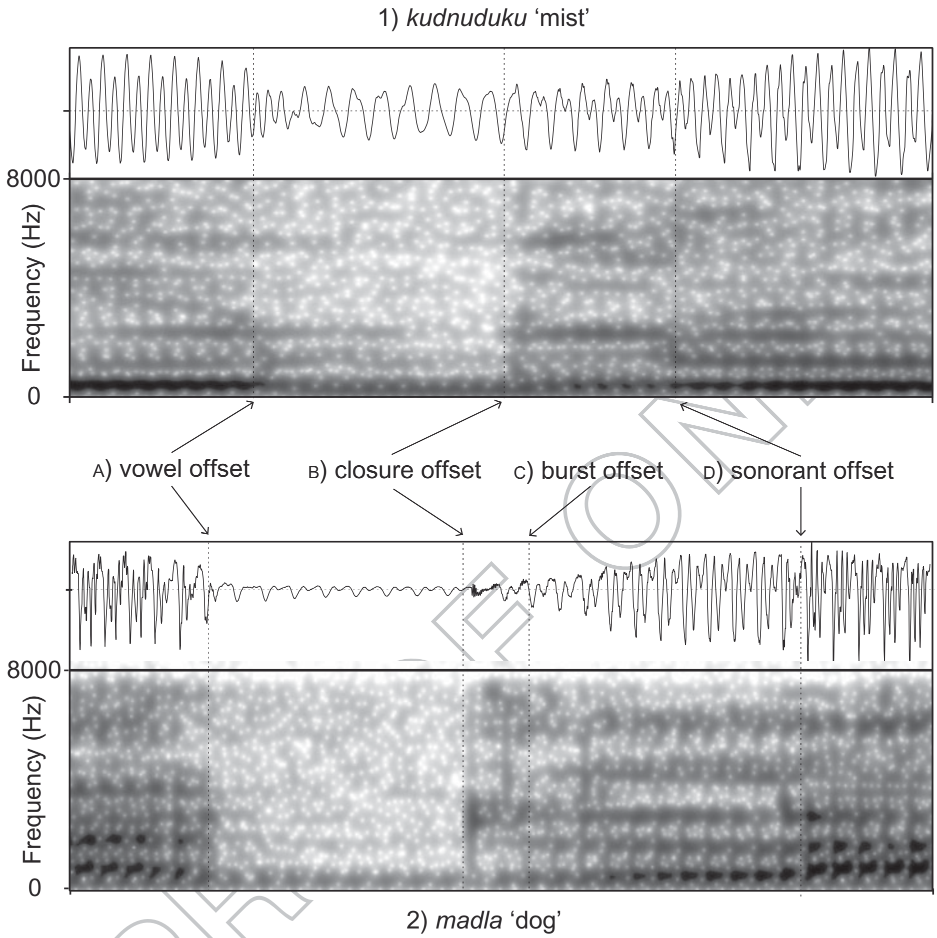

Figure 3 Partial waveforms and spectrograms of two Arabana words, (1) *kudnuduku* 'mist' and (2) *madla* 'dog', annotated for acoustic landmarks of, respectively, the nasal or lateral sonorant—between points (B/C) and (D)—and the preceding homorganic oral closure—between points (A) and (B/C)

in duration from phonetically related singletons, then this favours a phonological analysis of the sequence as the realization of a singleton at some level. If a phonetic sequence is significantly greater in duration than phonetically related singletons, then this disfavours a phonological analysis of the sequence as the realization of a singleton.

We examined the duration of the pre-stopped laterals and nasals, and compared them with their oral and sonorant counterparts, in order to see if the pre-stopped laterals and nasals were longer (i.e. less like single segments in duration). Table 7 displays the mean durations aggregated over individual places of articulation, along with token counts with each consonant type–place combination (e.g. 14 tokens for alveolar stops).

Table 7 Mean durations (*M*) and standard error of the mean (*SEM*), in milliseconds aggregated over individual places of articulation across *n* tokens (*N* = 423) from Datasets 1 and 2

			Closure		Burst		Sonorance		Total	
Consonant type	Place	*n*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Oral stop	Labial	44	81.7	2.59	29.9	1.9	–	–	111	2.74
	Dental	19	69.7	5.24	28.0	1.36	–	–	97.7	4.8
	Alveolar	14	72.5	7.97	39.7	2.6	–	–	95.1	7.12
Plain lateral	Dental	6	–	–	–	–	87.6	4.92	87.6	4.92
	Alveolar	30	–	–	–	–	93.4	2.79	93.4	2.79
Plain nasal	Labial	7	–	–	–	–	76.3	4.22	76.3	4.22
	Dental	19	–	–	–	–	80.9	3.55	80.9	3.55
	Alveolar	15	–	–	–	–	91.8	4.59	91.8	4.59
Pre-stopped lateral	Dental	6	56.9	4.31	–	–	90.6	14	148	15.4
	Alveolar	144	42.8	1.17	11.1	0.377	86.7	2.1	130	2.43
Pre-stopped nasal	Labial	21	63	3.67	–	–	77.5	4.47	140	5.91
	Dental	39	45.3	2.45	–	–	78.7	2.15	124	2.66
	Alveolar	59	46.8	1.79	–	–	70.5	2.96	117	2.98

As can be seen from the token counts, the number of observations between each consonant class–place combination are highly unbalanced. Consequently, we do not present inferential statistics by place as predictor variable for Datasets 1 and 2, and the following discussion presents results aggregated across all place oppositions.

Figure 4 displays the mean durations of components across the Arabana consonant types examined. Overall, the mean durations of pre-stopped nasals and laterals were found to be greater than the mean durations of plain nasals, plain laterals and oral stops.

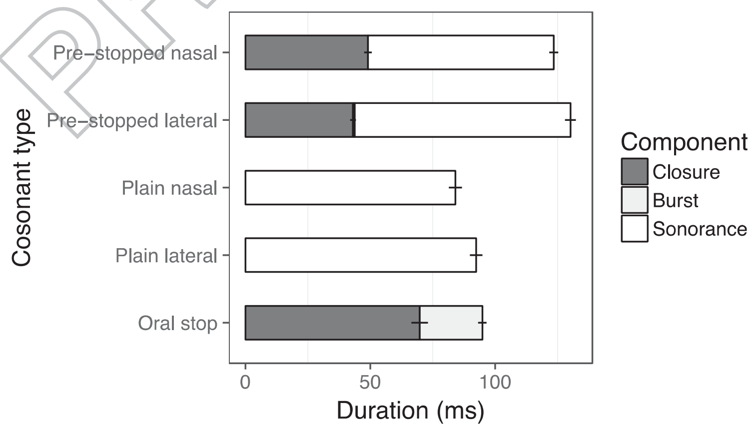

Figure 4 Mean duration of components (burst, closure, sonorance) of various Arabana consonant types (pre-stopped nasals and laterals, plain nasals and laterals, oral stops), aggregated over 423 tokens from Datasets 1 and 2. Error bars represent the standard error of the mean

Table 8 Aggregate mean durations and standard error of the means for components given in Figure 4 (N = 423 tokens, from Datasets 1 and 2)

		Closure		Burst		Sonorance		Total	
Consonant type	*n*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Oral stop	77	77.0	2.48	30.5	1.29	-	-	104.7	2.5
Plain lateral	36	–	–	–	–	92.4	2.46	92.4	2.5
Plain nasal	41	–	–	–	–	84.1	2.59	84.1	2.6
Pre-stopped lateral	150	43.3	1.16	11.1	0.377	86.8	2.08	130.9	2.4
Pre-stopped nasal	119	49.1	1.47	–	–	74.4	1.83	123.6	2.1

A one-way analysis of variance (ANOVA) indicated a main effect of consonant type on the total duration, $F(4, 418) = 47.1$, $p < 0.000$, $\eta_p^2 = 0.311$. Post-hoc analyses via Tukey's Honest Significant Difference (HSD) test indicated that the total mean durations of pre-stopped nasals and pre-stopped laterals were significantly longer than those of both plain nasals and plain laterals, as well as those of oral stops. The total mean durations of oral stops were found to be significantly longer than those of plain nasals, but not plain laterals. Pre-stopped laterals and pre-stopped nasals were found not to differ significantly in mean total duration. Plain laterals and plain nasals were also found to not differ significantly in their mean total durations. All mean total durations and the standard error of the means are reported in Table 8.

4.5. Results for Dataset 3

Figure 5 displays the mean durations of components across the Arabana consonant types examined for data sourced from Dataset 3. Aggregated over place of articulation, the mean durations of pre-stopped nasals and laterals were found to be greater than the mean durations of plain nasals, plain laterals and oral stops—as was found for Datasets 1 and 2 (cf. Figure 4). A one-way ANOVA indicated a main effect of consonant type on the total duration, $F(4, 546) = 105.6$, $p < 0.000$, $\eta_p^2 = 0.436$. Post-hoc analyses via Tukey's HSD test indicated that the mean total durations of both pre-stopped laterals ($M = 156$ ms, $SEM = 3.20$ ms) and pre-stopped nasals ($M = 146$ ms, $SEM =$ 1.76 ms) were significantly longer than the mean total durations of both plain laterals ($M = 107$ ms, $SEM = 2.64$ ms) and plain nasals ($M = 110$, $SEM = 1.92$ ms), as well as those of oral stops ($M = 102$, $SEM = 2.44$), replicating the findings from Datasets 1 and 2 above. Likewise, the mean total durations of plain nasals and plain laterals did not differ from each other. By contrast, the mean total duration of oral stops differed neither significantly from those of plain nasals nor plain laterals (oral stops differed significantly only from plain nasals in Datasets 1 and 2), and the mean total durations of pre-stopped laterals were found to be significantly longer than those of pre-stopped nasals (10 ms mean difference in Dataset 3; they did not differ in Dataset 1). In sum, with the exception of some minor variability, the main findings

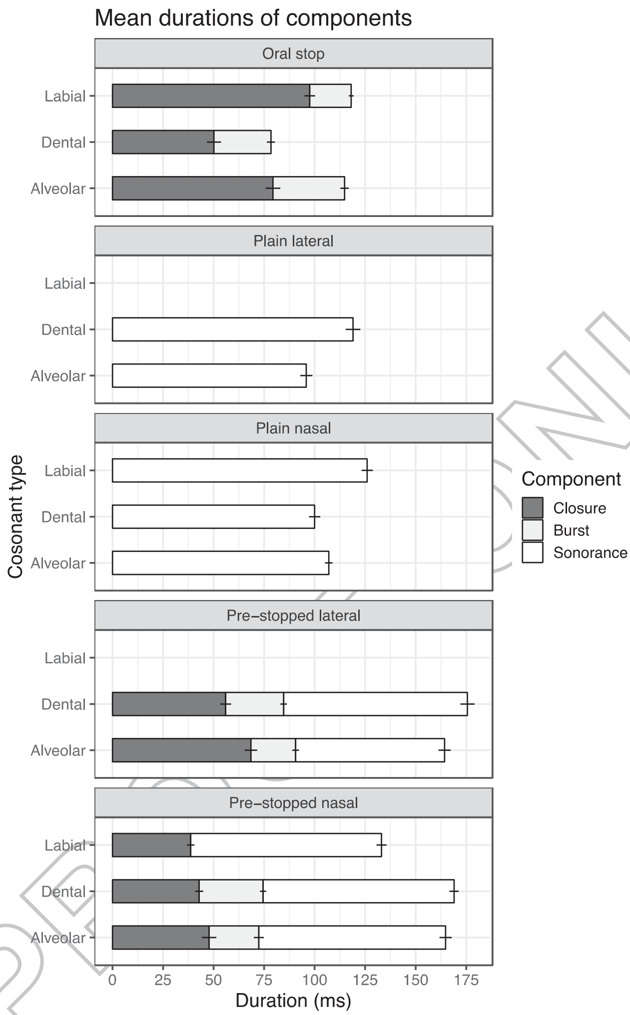

Figure 5 Mean duration of components (burst, closure, sonorance) of various Arabana consonant types (pre-stopped nasals and laterals, plain nasals and laterals, oral stops), aggregated over 551 tokens from Dataset 3. Error bars represent the standard error of the mean

of durational differences between plain and pre-stopped laterals and nasals in Arabana from Datasets 1 and 2 were replicated in Dataset 3 at the aggregate level.

Table 9 provides total mean durations (second right-most column) for each of the five consonant types (oral stop, plain lateral, plain nasal, pre-stopped lateral and pre-stopped nasal) and three possible places of articulation (labial, alveolar, dental). A two-way ANOVA was conducted to examine the effect of consonant class and place of articulation on total duration. There was a statistically significant

Table 9 Aggregate mean durations and standard error of the means for components given in Figure 5 ($N = 551$ tokens, from Dataset 3)

			Closure		Burst		Sonorance		Total	
Consonant type	Place	*n*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Oral stop	Labial	48	97.6	2.63	20.5	1.20			118	2.21
	Dental	41	50.2	3.47	28.2	1.95			72.9	3.45
	Alveolar	40	79.4	3.65	35.4	2.11			114	3.16
Plain lateral	Dental	40					119	3.63	119	3.63
	Alveolar	43					95.9	3.01	95.9	3.01
Plain nasal	Labial	42					126	2.8	126	2.80
	Dental	45					100	2.79	100	2.79
	Alveolar	43					107	1.86	104	3.09
Pre-stopped lateral	Dental	40	56.0	2.69	28.7	1.60	90.9	3.52	163	3.83
	Alveolar	44	68.5	3.09	22.1	1.68	73.7	3.03	148	4.81
Pre-stopped nasal	Labial	40	38.7	1.85			94.4	2.48	133	2.10
	Dental	41	42.9	2.00	31.6	1.50	94.5	2.30	149	2.84
	Alveolar	44	47.8	3.56	24.6	2.50	92.4	3.01	154	3.07

interaction between the effects of consonant class and place of articulation, $F(6, 538) = 31.95$, $p < 0.000$, $\eta_p^2 = 0.263$. Post-hoc analyses using Tukey's HSD are reported below.

As seen in the two-way interaction plot provided in Figure 6, the effect of place of articulation on total duration varied by consonant type. Within oral stops, the mean duration of dentals was significantly shorter than both labial and alveolar stops (2a vs. 1a; 2a vs. 3a), while the mean duration between the latter two did not differ significantly from each other (1a vs. 3a). Within plain nasals, the mean duration of labials was significantly longer than both dental and alveolar nasals (1b vs. 2b; 1b vs. 3b), while the mean durations of the latter two did not differ significantly from each

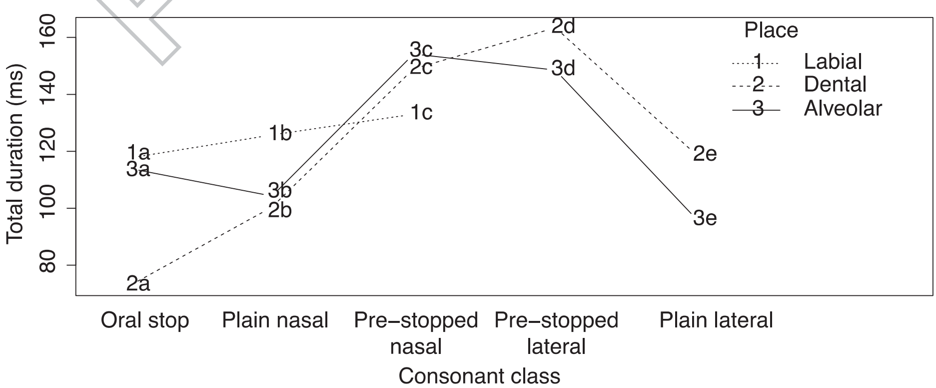

Figure 6 Two-way interaction plot between five consonant types (oral stop, plain nasal, pre-stopped nasal, pre-stopped lateral, plain lateral) and three places of articulation (labial, dental, alveolar)

other (2b vs. 3b). Within pre-stopped nasals, the mean duration of labials was significantly shorter than both dental and alveolar pre-stopped nasals (1c vs. 2c; 1c vs. 3c), while the mean duration of the latter two did not differ significantly from each other (2c vs. 3c). Within pre-stopped laterals, the mean duration of alveolar and dentals did not differ significantly from each other (2d vs. 3d). Within plain laterals, the mean duration of dentals was found to be significantly longer than the mean duration of alveolars (2e vs. 3e).

Across consonant types for labials, only the mean duration of pre-stopped labial nasals was significantly longer than those of labial oral stops (1c vs. 1a). Mean durations of plain labial nasals did not differ significantly from labial oral stops (1b vs. 1a), or pre-stopped labial nasals (1b vs. 1c). For dentals, the mean duration differed significantly across all consonant types, except for the mean duration between pre-stopped dental nasals and pre-stopped dental laterals (2c vs. 2d). For alveolars, the mean duration differed significantly across all consonant types, except for those between oral stops and plain nasals (3a vs. 3b), plain nasals and plain laterals (3b vs. 3e), and pre-stopped nasal and pre-stopped laterals (3c vs. 3d).

The critical point from Figure 6 is that the overall duration of pre-stopped labial nasals is not significantly longer than the overall duration of plain nasals in Dataset 3. When place is not evaluated as a factor, and comparison is only on the basis of manner classes, then the overall duration of both pre-stopped laterals and nasals was significantly longer than the overall duration of the plain stops, laterals, and nasals in all datasets. When place is evaluated as a factor, then a statistically significant difference still holds for the dental and the alveolar places. For the labial place, it holds only between pre-stopped nasals and plain stops. We consider a potential explanation for the exception of the labial place in §4.6.

4.6. *Distribution of Burst Realizations by Place of Articulation*

As discussed in the preceding §4.5, the pre-stopped labial nasal is distinctive among pre-stopped sequences from Dataset 3 in that its overall duration is not significantly longer than the overall duration of the plain nasal. The pre-stopped labial nasal shows another distinctive pattern. It is the only segment type involving closure which consistently fails to show burst.

In order to investigate any potential relation between these two distinctive facts, we examined the distribution of burst by token and by manner + place categories in our datasets. Table 10 displays the mean proportions of burst realizations for types within our datasets. For example, for single type eliciting the labial oral stop in Dataset 3, *waparnda* 'to hunt/seek', 97.9% (47 of 48 tokens) were found to have been produced with a release burst. A similar consistency was also found in Datasets 1 and 2, in which seven types (total 44 tokens = median 6 tokens per type) were found to have a 98.7% consistency in burst realization for the labial oral stop.

As Table 10 illustrates, a burst is less likely to occur if the closure is followed by a sonorant consonant than if closure is followed by a vowel. As such, a following

Table 10 Mean proportions (Prop.) of burst realizations across tokens for each type in Datasets 1–3

		Datasets 1 and 2			Dataset 3		
		Prop.	*Tokens*	*Types*	*Prop.*	*Tokens*	*Types*
Oral stop	Labial	98.7	44	7	97.9	48	1
	Dental	100	19	3	80.5	41	1
	Alveolar	58.3	14	2	97.5	40	1
Pre-stopped lateral	Dental	0.00	6	1	57.5	40	1
	Alveolar	8.02	144	16	59.1	44	1
Pre-stopped nasal	Labial	0.00	21	3	0.00	40	1
	Dental	0.00	39	7	36.6	41	1
	Alveolar	0.00	59	8	56.8	44	1

Table 11 Mean burst durations for Datasets 1–3. Figures repeated from Table 7 (Dataset 1 and 2) and Table 9 (Dataset 3)

		Datasets 1 and 2		Dataset 3	
		M	*SEM*	*M*	*SEM*
Oral stop	Labial	39.7	2.60	20.5	1.20
	Dental	28.0	1.36	28.2	1.95
	Alveolar	29.9	1.90	35.4	2.11
Pre-stopped lateral	Dental	–	–	28.7	1.60
	Alveolar	11.1	0.377	22.1	1.68
Pre-stopped nasal	Labial	–	–	–	–
	Dental	–	–	31.6	1.50
	Alveolar	–	–	24.6	2.50

sonorant consonant may reasonably be described as inhibiting bursts. As Table 10 also illustrates, place also appears to be a relevant factor. The effects of a following sonorant consonant are strongest for the labial place, less with dental place and least with alveolar place.

We note that if the pre-stopped labial nasals had shown burst data similar to the other categories involving closure in Dataset 3, then it would have likely been significantly longer than the plain labial nasals. We repeat the burst data for Datasets 1 and 2 and the burst data for Dataset 3 in Table 11.

There is evidently some variation in the burst duration data, but most durations are in the 20–35 ms range. In Dataset 3, if the pre-stopped labial nasal had consistently shown a 20 ms burst on average, which is that shown by the labial stop, then the overall duration of the pre-stopped labial nasal would have been 153 ms, on average. This would have been significantly longer than the duration of the plain nasal.[11]

11 A *t*-test revealed significant differences in mean total duration when plain nasals were compared to pre-stopped nasals with the addition of randomly-sampled burst data from labial oral stops: plain labial nasals (*M*

This suggests that there are two counteracting forces which affect the phonetic expression of pre-stopped sequences. One is a preference for full temporal expression as [closure + burst + sonorant]. The other is a dispreference, mediated by place, against the expression of burst if there is a following sonorant consonant realization. Full evaluation of these hypotheses would require the collection of further experimental data, and as such is beyond the scope of this paper.

4.7. Consistency of Pre-stopping

As discussed in §3, contrastive pre-stopping shows consistency in production whereas non-contrastive pre-stopping does not. We examined our datasets for consistency in production, where this was possible. We were unable to calculate consistency of pre-stopping for Dataset 2 (from speaker Laurie Short) because the data were not collected under experimental conditions, and therefore there was no control over the number of tokens for each type. Consequently, it was not possible to perform intra-type consistency calculations. By contrast, with Datasets 1 and 3 (i.e. only for Sydney Strangways' data) the number of tokens for each type was controlled, and consequently, it was possible to calculate consistency of pre-stopping by type.

For each type within Dataset 1, we counted the number of pre-stopped and plain productions of the segment of interest. In a total of 49 types (310 tokens), 45 types were produced with 100% consistency while four types (11 tokens) were found to have been produced with variation in pre-stopping across the tokens. For three of these four types,[12] the variable token was only the initial or only the final token. For one type, *mudluparnda* 'sandhill', tokens 2 and 3 (out of 8) were produced with pre-stopping, i.e. [mʊ**dl**u …], while the others were not, i.e. [mʊ**l**u …]; we thus excluded all tokens of this word from our analysis. Overall, Sydney shows a very high degree of intra-speaker consistency in pre-stopping ($45/49 = 91.8\%$ types produced without variation in pre-stopping). For Dataset 3, in a total of five types (209 tokens), 100% of the tokens (range: 40–44 tokens per type) were produced with pre-stopping.

We performed the same calculations on the dataset for non-contrastive lateral pre-stopping from Harvey *et al.* (2015), for which there were seven Kaytetye participants. For each speaker in the dataset, we calculated their consistency of pre-stopping across the Kaytetye types and report these calculations in Table 12. The intra-speaker variability in pre-stopping can be seen from the columns of this table: e.g. speaker S01 produces *alyepe* 'softly' with 100% pre-stopping, but *Alyeke*, a place name, with less than 50% pre-stopping. The inter-speaker variability can be seen from the rows of this table: e.g. in contrast to S01, speaker S02 produces *alyepe* with 87.5% pre-stopping, and speaker S03 with 75.0%. Thus, non-contrastive lateral pre-stopping in Kaytetye shows neither intra- nor inter-speaker consistency.

$= 126$ ms, $SD = 18.2$ ms) vs. pre-stopped labial nasals + labial oral stop burst durations ($M = 154$ ms, $SD = 16.1$ ms), $t(79.6) = 7.46$, $p < 0.000$, $d = 1.69$.

[12] *kadlara* 'cloud', *madla-yari* 'Stuart's pea', *mudlhurru* 'drizzle'.

Table 12 Consistency calculations (in percentage of tokens pre-stopped) for lateral pre-stopping by seven Kaytetye subjects across seven types

	Subject						
Type	S01	S02	S03	S05	S06	S11	S13
aleke	50.0	100	50.0	0	33.3	37.5	50.0
aleme	57.1	75.0	66.7	28.6	14.3	75.0	0
alhekere	75	37.5	33.3	0	33.3	37.5	33.3
Alyeke	42.9	100	75.0	16.7	0	50.0	100
alyepe	100	87.5	60.0	33.3	0	37.5	66.7
arlemenye	50.0	0	33.3	0	66.7	100	50.0
arlepe	16.7	25.0	0	40.0	50.0	75.0	50.0

As mentioned previously (§3), the overall consistency for contrastive nasal pre-stopping in Kaytetye is reported as 97%, and shows both intra- and inter-speaker consistency. In terms of intra-speaker consistency, our Arabana data agree with the Kaytetye contrastive nasal pre-stopping and disagree with the Kaytetye non-contrastive lateral pre-stopping. Given that our experimental datasets consist of a single speaker, Sydney Strangways, we are unable to comment on inter-speaker consistency for pre-stopping in Arabana.

4.8. Summary

Pre-stopped lateral and nasal sequences in Arabana are distinguished from plain stops by the consistent production after closure of a sonorant consonant with a mean duration of not less than 73.7 ms. This is the shortest mean duration of following sonorance, found in the pre-stopped alveolar lateral category in Dataset 3 (Table 9). Pre-stopped sequences are distinguished from plain laterals and plain nasals by the consistent production of closure with a mean duration of not less than 38.7 ms. This is the shortest mean duration, which is found with pre-stopped labial nasals in Dataset 3 (Table 9).

The mean durations of consistently produced closure in Arabana are less than those for consistently produced closure in Kaytetye (Table 4). There is one case where the mean duration of closure which is not consistently produced approaches that of consistently produced closure in Arabana. In Kaytetye, the mean duration of closure in the pre-stopped dental lateral category is 37 ms (Table 4). However, this is the longest mean duration for closure which is not consistently produced, and mean durations for closure of this kind in all other pre-stopped categories across Kaytetye, Gupapuyngu and Warlpiri are less than 30 ms (Table 4).

Pre-stopped lateral and nasal sequences are also distinguished in nearly all cases from the corresponding plain stops, laterals and nasals by the fact that their overall duration is significantly longer. The one exception, discussed in §4.5 and §4.6, is that the overall duration of the pre-stopped labial nasal is not significantly longer than the overall duration of the plain labial nasal in Dataset 3.

5. Phonological Analyses of the Plain vs Pre-stopped Opposition

5.1. Complex Segment vs Clusters

There are four principal analyses of the pre-stopped sequences. These are illustrated in Table 13 with *madla* 'dog'.

The major division is between the complex segment and the cluster analyses. We begin by considering this major division. In general terms, the complex segment analyses have the benefit of a simpler phonotactics at the cost of a more complex segmental inventory. The cluster analyses have the benefit of a simpler segmental inventory at the cost of a more complex phonotactics. The choice between the two types of analysis depends on the comparative cost–benefit analysis in each case.

The opposition between complex segments and clusters was a research topic in the initial stages of phonological research. Trubetzkoy (1969: 55–62) suggests a number of criteria for analysis of two phonetically distinct components as a complex segment. The principal phonotactic and quantitative criteria are summarized in example (23).

(23) (a) The components must be tautosyllabic
(b) The components must be homorganic
(c) The combined duration of the components should not exceed the duration of other phonemes
(d) The components appear in positions not otherwise phonotactically available to clusters

The potential of these criteria was debated in the early literature (Martinet 1939). However, these debates were not a focus of subsequent research, and there is no well-tested consensus on criteria for evaluating complex segment vs. cluster analyses. Devine (1971) proposes that phonotactic criteria, particularly commutation with Ø, are the main criteria. Devine compares two potential analyses of English [p^{h}æt]: /pæt/ vs /phæt/. While [p] commutes with Ø, as [hæt] /hæt/ is a word, the [h] does not, as there are no word forms [pæt] in English. Consequently, [p^{h}] is best analyzed as a complex allophone of /p/.

Given that analyses agree that phonotactics is central to the opposition between complex segment vs cluster analyses, the starting point for comparative evaluation of the two analyses in Arabana is a consideration of the phonotactics of pre-

Table 13 Phonological analyses of phonetic pre-stopping

		Segmental structure	Syllabification
Complex segment	Pre-stopped sonorant	ma^{d}la	ma.^{d}la
	Stop with sonorant release	mad^{l}a	ma.d^{l}a
Cluster	Heterosyllabic	madla	mad.la
	Tautosyllabic	madla	ma.dla

stopped and plain realizations. In this case, a comparison between Arabana and Arandic assists in highlighting the relevant points. Among the Arandic varieties, the most detailed description of pre-stopping is that for Kaytetye (Harvey *et al.* 2015). Consequently, we compare the phonotactics of Arabana with those of Kaytetye.

In both Arabana and Kaytetye, triple sequences of [+ consonantal] segments are generally absent, a pattern which holds for most Australian languages (Dixon 2002: 656–658). However, Kaytetye does allow triconsonantal [Stop][Nasal][Stop] sequences, as shown in Tables 14 and 15. In all cases, the initial [Stop][Nasal] pair is homorganic.

As also illustrated in Tables 14 and 15, corresponding to each cluster with an initial pre-stopped nasal, there is a cluster with an initial plain nasal. These patterns raise two significant issues for a cluster analysis of pre-stopping in Kaytetye. The first issue is a systematic correspondence between plain and pre-stopped nasals. If pre-stopped nasals are analyzed as clusters, then it is not possible to capture this correspondence straightforwardly. If pre-stopped nasals are analyzed as complex nasal segments, then it is possible to generalize about the distribution of a superclass of nasals, which has two subclasses: plain, pre-stopped.

It should be noted that of the two complex segment analyses, pre-stopped sonorant and sonorant released stop, phonotactic patterning supports only the pre-stopped sonorant analysis in Kaytetye. In clusters, plain stops may appear only in final position in Kaytetye; e.g. there is no /lpm/ corresponding to /lp/. Therefore, there is no support for positing a superclass of stops with two subclasses: plain release, sonorant release.

The second issue raised by the [Stop][Nasal][Stop] sequences relates to the usual patterning of triple sequences of [+ Consonantal] segments in Australian languages. These generally conform to the formula [Liquid] + [Nasal] + [Stop], with the [Nasal] + [Stop] sequence usually being homorganic (Dixon 2002: 657). This sequence

Table 14 Kaytetye nasal clusters—Final C homorganic

Labial	Alveolar	Retroflex	Dental	Palatal	Velar
mp	nt	ɳʈ	n̪t̪	ɲc	ŋk
pmp	tnt	ʈɳʈ	t̪n̪t̪	cɲc	kŋk

Table 15 Kaytetye nasal clusters—Final C heterorganic

		$C_1(C_2)$			
		Alveolar		Retroflex	
C_{FIN}	*p*	np	tnp	ɳp	ʈɳp
	m	nm	tnm	ɳm	ʈɳm
	k	nk	tnk	ɳk	ɳŋ
	ŋ	nŋ	tnŋ	ʈɳk	ʈɳŋ

is standardly syllabified under the Sonority Sequencing Generalization [SSG] with a syllable boundary between the [Nasal] and the [Stop]: i.e. (C)VLN.SV.

Kaytetye does not have [Liquid] + [Nasal] + [Stop] sequences, and syllabification of the Kaytetye triconsonantal sequences in Tables 14 and 15 is not straightforward. The potential syllabifications of VSNSV and VSNNV are VS.NSV, VS.NNV or VSN.SV, VSN.NV. These potential syllabifications involve either NS, NN onsets or SN codas, both of which violate the SSG. The VS.NSV and VS.NNV syllabifications do not satisfy the Syllable Contact Law [SCL], which states that codas are preferentially of equal or greater sonority than following onsets (Murray & Vennemann 1983), i.e. $V_1C_1.C_2V_2$, $\textsc{son}_{C1} \geq \textsc{son}_{C2}$. An analysis of the Kaytetye pre-stopped nasals as complex segments does not encounter these issues. Both syllabification and cluster structure are straightforward under a complex segment analysis.

The phonotactics of plain and pre-stopped realizations in Arabana are very different. The inventory of clusters conforming to the SCL is set out in Tables 16 and 17 (Hercus 1994: 52–54).

In addition to these clusters, there are three clusters which do not conform to the SCL: /pm, tm, ŋm/. These all have only a few attestations, and most attestations involve the transitive verbalizing suffix *-ma*, either synchronically or diachronically (Hercus 1994: 53–54).[13]

There are no clusters involving pre-stopped realizations: i.e. *VS(N/L)CV. Therefore, there is no correspondence between the distribution in clusters of pre-stopped and plain realizations for either nasals or laterals. To the contrary, pre-stopped realizations are found only in the environment V_V, which is the general environment for clusters in Arabana. Therefore, there are no gains in phonotactic description to positing a lateral superclass including plain and pre-stopped lateral, and a nasal superclass including plain and pre-stopped nasals. Rather, these would be superclasses about which no generalizations could be made.

In addition to this superclass cost, there are two types of costs to the segmental inventory in analyzing pre-stopped realizations as complex segments. These costs are a substantial increase in the size of the inventory (five more), and a substantial increase in the number of manner classes (two more). If the pre-stopped realizations are analyzed as clusters, then Arabana has an inventory of 21 consonants. If they are analyzed as complex segments, then there are 26 consonants, which is an increase of 24% in the size of the inventory. If pre-stopped realizations are analyzed as clusters, then there are six manner classes in the inventory. If they are analyzed as complex segments, then there are eight manner classes, which is an increase of 33% in the manner classes. The cluster analyses do not face these costs: they do not involve unsupported superclasses and they involve significantly less complex segmental inventories.

[13] The orthographic sequence <pm> is attested only in the Wangkangurru verbal form *yarap-ma* 'to lift up', which involves the *-ma* transitive verbalizer. We do not have phonetic data on this form. Consequently, it is not known whether the orthographic distinction between the <pm> cluster in this form and the <bm> pre-stopped nasal has any phonetic basis, or whether it is solely motivated by morphological considerations.

Table 16 Arabana homorganic clusters

Labial	Alveolar	Retroflex	Dental	Palatal	Velar
mp	nt	ɳʈ	n̪t̪	ɲc	ŋk
	lt	ɭʈ	l̪t̪	ʎc	

Table 17 Arabana heterorganic clusters

		C_1					
		n	ɳ	l	ɭ	ʎ	r
C_2	p	np	ɳp	lp	ɭp	ʎp	rp
	k	nk	ɳk	lk	ɭk	ʎk	rk
	t̪						rt̪
	c						rc

5.2. Tautosyllabic vs Heterosyllabic Clusters

In Arabana, an important factor in the choice between the two cluster analyses—heterosyllabic [ˈmad.la] vs. tautosyllabic [ˈma.dla] or [ˈmadl.a]—is the metrically constrained distribution of pre-stopping in the language. As discussed in §2, pre-stopping requires a preceding stressed vowel. In other words, there is a local prosodic relationship between two adjacent phonetic realizations, a stressed vowel and a pre-stopped sequence. Local prosodic relationships are standardly modelled in terms of common membership of a constituent at a specific level in the prosodic hierarchy. In this case, the relevant level is that of the syllable. The potential syllabification options for pre-stopped sequences are illustrated in example (24) with *madla* 'dog'.

(24) A. [ˈmadl.a] B. [ˈma.dla] C. [ˈmad.la]

Option A establishes a local relation between the stressed vowel and the entire pre-stopped sequence. However, Option A violates the SSG as it requires analysis of /dl/ as a tautosyllabic coda sequence. Further, it requires that the following syllable is onsetless. In Arabana, onsetless syllables otherwise appear only at the left edges of prosodic words (Hercus 1994: 31–32). Consequently, Option A may be rejected. Option B is the syllabification under the Tautosyllabic Cluster hypothesis. Option B satisfies the SSG and does not involve medial onsetless syllables. However, the stressed vowel and the pre-stopped sequence are not in a local prosodic relationship under Option B. Consequently, it offers no motivation for the metrical constraints on pre-stopping in Arabana. Option C is the syllabification under the Heterosyllabic Cluster analysis. It establishes a local relationship between the stressed vowel and the stop component of the pre-stopped sequence. It satisfies the SSG and does not involve onsetless syllables. Therefore, Option C is the preferred analysis of pre-stopped sequences in Arabana.[14]

While the Heterosyllabic Cluster analysis accommodates the metrical licensing of pre-stopping in Arabana, it comes at the cost of dispreferred heterosyllabic relations. The Heterosyllabic Cluster analysis violates the SCL preference for codas not to be less sonorous than following onsets. It is necessary to independently allow for violations of the SCL in Arabana, as there are a few examples of the clusters /pm/ and /tm/ which violate the SCL: e.g. *witma-* [wit.ma] 'to steal'. These /pm/ and /tm/ violations were historically and are perhaps synchronically heteromorphemic clusters (Hercus 1994: 53–54).[15] Australian languages rarely have morphophonemic processes affecting heteromorphemic clusters (Baker 2014: 169). Consequently, violations of the SCL across morpheme boundaries are not uncommon. Analysis of pre-stopped laterals and nasals as heterosyllabic clusters in Arabana requires extensive violation of the SCL in morpheme-medial position, which is unusual in Australian languages.

If preferred heterosyllabic relations became a priority, then this would favour the Tautosyllabic hypothesis. The syllabification under this analysis—*ma.dla* 'dog'—would not violate the SCL. On the other hand, it does involve a violation of the dispreference for onset clusters. In Australian languages, onset clusters are uncommon and those that do occur usually consist of either homorganic nasal-stop clusters or dorsal/labial stop + apical liquid: e.g. /br/, /gl/ (Dixon 2002: 653–654). Under the Tautosyllabic analysis, onset clusters would be homorganic stop + nasal and stop + lateral sequences. The Tautosyllabic analysis also predicts that pre-stopped sequences could spread to all possible onset positions, including word-initial position, and this is not the case in Arabana.[16]

5.3. Motivations for Metrical Licensing

Though the Heterosyllabic Cluster analysis accommodates metrical licensing of pre-stopping, it does not provide a direct motivation for the actual metrical constraints. The Heterosyllabic Cluster analysis proposes that a syllable boundary may be placed between an obstruent and a sonorant, even though this violates the SCL and even though violation of the SCL in morpheme-medial position is typologically unusual.

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14 The complex segment analyses face the same problems as Options A and B. Taking *madla* 'dog' as an example: (i) /ma^{d}l.a ~ mad^{l}.a/ syllabifications model the prosodic relation at the cost of medial onsetless syllables; (ii) /ma.^{d}la ~ ma.d^{l}a/ syllabifications do not involve medial onsetless syllables, but fail to model the prosodic relationship.

15 Hercus (1994: 138) notes that the corresponding forms in Wangkangurru contain homorganic stop-nasal sequences, which can then be analyzed as pre-stopped sequences:

Arabana	Wangkangurru	
thatma-	*thadna-*	to leave
witma-	*widnangka-ma*	to steal
itma-	*ibma*	to touch

16 There are both manner and place restrictions on word-initial position in Arabana. Apicals are not attested initially. Laterals also are not attested initially, with the exception of a very few /lh/ initial roots. These restrictions would militate against the appearance of /dn/, /dl/ and /dlh/ in initial position, but they would not operate against the initial appearance of /bm/ or /dnh/.

Table 18: Realizations of post-tonic nasals and laterals

Initial segment	Anterior nasal	Anterior lateral	Posterior nasal/lateral
C[+ nasal]	Short	Pre-stopped	/ɳ/ Short
V	Long	Long	/ɳ/ Short
Other	Pre-stopped	Pre-stopped	/ŋ/ Long
			/ɳ/ Short

Note: The description of consonantal lengthening in Hercus (1994) is incomplete. She states that /ɳ/ is always short and that /ŋ/ is long when the initial segment is [–nasal] consonant. However, there is no discussion of the realization of the velar nasal in other environments, nor any discussion of the realizations of the retroflex lateral, the palatal nasal and the palatal lateral.

Given this, there is no reason why pre-stopped sequences should not also appear following metrically weak vowels: i.e. putative monomorphemic lexical root forms such as *kurudna* should be possible, but they are unattested.

The motivations for the metrical constraints must be sought elsewhere. As discussed in §1, Round (2014: 89–91) proposes that articulatory considerations were central to the development of pre-stopping, and that pre-stopping is most likely to cross perceptual thresholds in segments of long duration. Hercus (1994: 38–39, 43–44) proposes that there is an essentially complementary distribution in Arabana between lengthening and pre-stopping in post-tonic position, as summarized in Table 18.

Post-tonic lengthening of sonorants is a widely attested phenomenon in Australian languages (Fletcher & Butcher 2014: 120–121). Round (2014), following Hercus (1994), suggests that pre-stopped consonants developed from long consonants. Given that a long consonant appeared in post-tonic position, pre-stopping could only develop following metrically strong vowels. Pre-stopping would not therefore, in origin, have targeted metrical strength per se. As not all long consonants developed into pre-stopped consonants, there are evidently other factors involved in the diachrony of pre-stopping, and Round (2014) discusses some of these (see also §6).

There is currently no quantitative data on the distribution of consonantal length in Arabana. Consequently, it is not possible to fully evaluate the potential role of segmental duration in the development of pre-stopping. It may be noted that some of the reported distinctions do not have obvious synchronic motivations. The underlying motivation for post-tonic lengthening is generally analyzed in terms of the local domain for the expression of metrical prominence being the tonic vowel and following consonantal material, with preceding consonantal material being excluded from this local domain. It is not immediately evident why oppositions outside this local domain should affect the expression of duration within the domain, particularly oppositions which have no inherent relation to duration, such as the opposition between [+ nasal] and [–nasal] initial consonants.

While Round's analysis foregrounds articulatory considerations as central factors in pre-stopping crossing perception thresholds, it also requires that there be some motivation for speakers to positively select the pre-stopped variants. Butcher (2006) proposes that pre-stopping provides better perceptual recovery of cues for place contrasts if the following consonant is a nasal:

> it seems reasonable to suppose that delaying the lowering of the velum for the nasal consonant for as long as possible would facilitate the maintenance of clear spectral cues to place of articulation in the pre-nasal vowel. (2006: 199)

The same motivation has been proposed for lateral pre-stopping (Butcher & Loakes 2008; Loakes *et al.* 2008). There are currently no experimental data testing the hypothesis that pre-stopping assists in the perception of place oppositions. Therefore, it is not possible to fully evaluate this analysis. Place oppositions among sonorants in Australian languages are not restricted by metrical factors. Consequently, the hypothesis that pre-stopping assists in the perception of place oppositions does not by itself predict that pre-stopping should only be found following metrically strong vowels.

Round (2014) agrees that nasal pre-stopping is motivated by perceptual augmentation of place contrasts in a following nasal, but argues that pre-stopping does not provide perceptual augmentation of place contrasts in a following lateral. Instead he proposes that pre-stopping in nasals establishes a gestural template, which may then be copied as a gestural template for laterals (Round 2014: 89). Overall, therefore, Round's analysis requires three theoretical constructs to motivate the metrical licensing of pre-stopping: (i) a distinctive association between segmental duration and pre-stopping; (ii) perceptual augmentation of place contrasts in nasals; and (iii) copying of gestural templates from nasals to laterals.

We propose an alternative analysis which requires only one motivation, that applies equally to nasals and laterals, for positive selection of pre-stopped realizations. This hypothesis is that the positive selection of pre-stopped realizations augments the perceptual salience of a prosodically strong position. In the case of Arabana, the particular prosodically strong position is primary metrical prominence.

The evident difference between the Heterosyllabic Cluster analysis as opposed to the Tautosyllabic Cluster and Complex Segment analyses is that the metrically strong syllable has more phonological structure under the Heterosyllabic Cluster analysis: /mad.la/ vs /ma.dla/, /ma.^{d}la/, /ma.d^{l}a/. It also involves a type of phonological structure, the obstruent coda, which is not found elsewhere in Arabana. This accords with the language universal that metrically strong syllables permit a greater quantity and/or greater range of phonological structure than do metrically weak syllables. It is therefore necessary to consider whether theories modelling augmentation in prosodic structure might offer a motivated analysis for the metrical constraints on pre-stopping.

Smith (2005) is the most detailed analysis of the motivations for augmentation in prominent positions. Smith proposes that augmentation increases the perceptual salience of phonologically strong positions. There are two distinct types of phonologically prominent positions, phonetically strong positions and positions which are strong because they play a central role in the psycholinguistics of speech processing (hereafter 'psycholinguistically' strong positions).

The class of phonetically strong positions includes stressed syllables. The class of psycholinguistically strong positions includes word-initial syllables and roots. In Arabana, the word-initial syllable is the primary stressed syllable, and is also the root-initial syllable, and consequently the initial syllable is both phonetically and psycholinguistically strong. Syllables with secondary stress are phonetically, but not psycholinguistically, strong. The distribution of pre-stopping correlates with this hierarchy of strength. Pre-stopping is principally found with primary stressed syllables and has a limited appearance in secondary stressed syllables. Given this, it appears that the obstruent coda contribution of pre-stopping to stressed syllables should be modelled as augmenting the processing of stressed syllables.

The general literature on phonetic enhancement of phonological contrast focuses on enhancement of segmental contrasts (Currie Hall 2011; Keyser & Stevens 2006; Wetzels & Nevins 2018). Wetzels and Nevins (2018: 834) define enhancement as 'the addition of a noncontrastive feature [F] to enhance a distinction between segments /X/ and /Y/ made otherwise only by a feature [G]'. Prosodic enhancement differs from segmental enhancement in that augmentation of stressed and/or initial syllables typically involves selection or addition of contrastive content: low sonority onsets, high sonority nuclei, bimoraic rimes involving either long vowels or codas which are geminate with the following onset (Smith 2005: 96–137). Pre-stopping involves addition of contrastive content, and therefore follows the general patterning of prosodic enhancement. However, it differs from the other methods of prosodic enhancement in that pre-stopping violates the SCL, whereas the other methods do not.

When codas augment a syllable, then they are usually modelled as doing so by contributing a mora such that the syllable rime is bimoraic. Cross-linguistically, there is a strong preference for sonorant codas, i.e. (C)(V)(N/L).C > (C)(V)(S).C, and a strong preference for moraic sonorants over moraic obstruents. There is no evidence that codas generally are moraic in Arabana. Consequently, we do not propose that the obstruent codas found in pre-stopped sequences augment stressed syllables by contributing a mora: i.e. we analyze both CV and CVC syllables as monomoraic in Arabana.[17] We do not propose that obstruent codas augment any of the direct phonetic correlates of stress. This accords with the analysis of augmentation as a phonological, rather than a phonetic, process. As Smith (2005: 5) observes 'while it is a particular phonetic characteristic that gives a phonetically strong position its special status, the position can nevertheless be the target of an M/Str constraint that manipulates properties unrelated to that characteristic'.[18]

For Arabana, we suggest that the perceptual contribution of obstruent codas lies in boundary marking, and that the more clearly bounded a constituent is the greater its

[17] Arabana does not appear to have underived long vowels.

[18] M/Str is an abbreviation for markedness constraints that make specific reference to strong positions (Smith 2005: 1).

perceptual salience. We suggest that obstruent codas in Arabana contribute to the perceptual salience of stressed syllables by more clearly demarcating their right boundaries. The canonical boundary signal is a pause, i.e. periods involving silence and/or non-linguistic sound which is usually aperiodic. The more closely a segment type approaches to this canonical boundary signal, the better it is as a boundary signal. Voiceless stops are the best boundary signals because they are voiceless and do not involve periodic energy. Voiced stops involve periodic energy only at the lowest frequencies where voicing is realized. Voiced sonorants are poor boundary signals because they are characterized by periodic energy across a wide frequency band.

Baker (2008: 248–268) analyzes the association between stop realizations and boundary marking for another Australian language, Ngalakgan, specifically in relation to geminate stop and stop clusters involving the glottal stop. Both involve extended periods of silence, unlike single stops. Baker (2008: 263) analyzes both stop sequences in terms of the feature 'spread glottis' and proposes the constraint in example (25).

(25) Voice[Off] Every [spread glottis] articulation demarcates the boundary of a constituent which is both an intonation domain and a morphological/prosodic category

Baker's analysis relates the boundary marking function of stop realizations to consistent cessation of voicing: i.e. complete absence of periodic energy. In Arabana, stop codas preceding nasals and laterals in our data are normally voiced (Figure 3), and Hercus observed that the stop part of pre-stopped nasals and laterals is always voiced (Hercus 1994: 37). Consequently, boundary marking cannot be related to complete absence of periodic energy. We suggest that the boundary marking function in Arabana relates to the fact that a voiced stop shows periodic energy only at the lowest frequencies, and consequently disrupts the continuous presentation of periodic energy across a wide frequency band which is the characteristic of sequences of sonorants. We hypothesize that when sequences such as /ˈCV.L/NV/ and /ˈCVS.L/NV/ are compared, there is a much greater change in phonetic structure at the right edge of Syllable 1 in /ˈCVS.L/NV/ than in /ˈCV.L/NV/.

Our proposal that obstruents are the preferred manner class for codas marking metrical boundaries does not require any revision of the standard analysis that sonorant is the preferred manner class for codas generally. Obstruent codas are a restricted coda class in Arabana, appearing only in the immediate post-tonic position. Sonorant codas may appear in all positions, including the position as the right boundary of a metrical head: e.g. *parkulu* 'two', *tjilparku* 'crane species'. Therefore, the unrestricted coda manner class is sonorant.

Our boundary marking proposal departs from Trubetzkoy's (1969: 273–297) foundational proposals on boundary signals in one significant respect. All of the boundary marking data discussed by Trubetzkoy involve the use of boundary signals to mark semantic boundaries, either word or morpheme boundaries. In Australian languages, the right boundaries of metrical heads can only contingently coincide with semantic boundaries, in the case where a language permits monosyllabic lexical roots. As

Arabana does not permit monosyllabic lexical roots, the right boundary for metrical heads never coincides with a semantic boundary.

We are not aware of other cross-linguistic data on the marking of prosodic boundaries which do not coincide with semantic boundaries. In the absence of such data, it is not possible to determine whether or not the phonetic/phonological marking of semantic boundaries differs systematically from the phonetic/phonological marking of prosodic boundaries which are not semantic boundaries. This is a topic for future research.

6. The Diachrony of Pre-stopping in Arabana

Hercus (1972, 1994: 37) provides evidence that pre-stopped sequences in Arabana derive historically from allophonic realizations of nasal and lateral phonemes in post-tonic position. In other words, the opposition between plain and pre-stopped realizations was historically non-contrastive.

We do not provide a complete analysis of the diachrony of pre-stopping in Arabana here.[19] Rather, we consider the development of pre-stopping as a boundary marking phenomenon. Synchronically in other Australian languages with non-contrastive pre-stopping, the oral closure component of the sonorant which constitutes the actual pre-stopping is comparatively short and highly variable in appearance. Consequently, we reconstruct the oral closure component of pre-stopped sonorants in Arabana as having originally been comparatively short in duration and highly variable in appearance.

It should be noted that this reconstruction of the duration of the oral closure component is logically independent of the reconstruction of overall segmental duration. As discussed in §5.3, Hercus (1994) and Round (2014) propose a historical relation between pre-stopping and overall segmental duration. Round (2014: 90) proposes that overall segment duration and pre-stopping duration correlate, with longer segments showing longer periods of pre-stopping. There is currently no quantitative evaluation of this hypothesis.

As discussed in §5.3, current analyses propose that non-contrastive pre-stopping is not a goal of production in and of itself. Rather, it arises as a by-product from other goals of production. For nasals, the goal of production is to temporally coordinate velum lowering with the attainment of oral closure. This production goal is motivated by a perceptual goal of avoiding nasalization of the preceding vowel. For laterals, the goal of production is temporal coordination of sagittal-plane constriction with coronal-plane contraction. Proposals vary as to the motivation for the lateral production target. In individual tokens, speakers may fail to attain the temporal coordination component of these goals of production. When they fail to do so, pre-stopped realizations arise.

When the failure of temporal coordination becomes sufficiently frequent, pre-stopping becomes available as a potential goal of production. We do not consider the threshold level of consistency required for this to happen, as this is beyond the

[19] In particular, we do not consider the role of place of articulation in conditioning pre-stopping, nor the constraint against *NVSN sequences (§2). Round (2014) discusses the role of place of articulation.

scope of this paper. However, we note that levels such as the 64% appearance of [ʈɭ] as an allophone of /ɭ/ in Kaytetye (Table 4) appear promising candidates. In Arabana, the motivation which has led to the actualization of pre-stopping as a goal of production is augmenting the processability of phonologically strong positions, specifically word-initial stressed syllables. It is possible that in other languages, there may be other motivations for the actualization of pre-stopping as a goal of production.

Whatever the motivation for actualization, once actualized the character of pre-stopping would change to match that of production goals generally. It would be consistently present, and would lengthen as lengthening assists in perceiving that the pre-stopping goal of production has been attained (Harvey *et al.* 2015: 246). We propose that this lengthening of the pre-stopping component was independent of overall segmental duration.

The available quantitative data support this hypothesis. As discussed in §3, there are data on contrastive and non-contrastive pre-stopping in Kaytetye and on non-contrastive pre-stopping in Gupapuyngu and Warlpiri. The Kaytetye data come from the pre-tonic position, and are not therefore directly comparable to the Arabana data (Harvey *et al.* 2015). The Gupapuyngu and Warlpiri data have a substantial component of post-tonic data. Warlpiri shows lengthening of post-tonic consonants (Butcher & Harrington 2003). The range of mean durations for pre-stopping in Warlpiri is 29–16 ms, and the range of mean durations in Gupapuyngu is 21–17 ms (Table 4). By contrast the range of mean durations for pre-stopping in Arabana is 69–39 ms (Table 8, Table 9).

We may consider a reconstruction of Arabana where sonorants were long post-tonically and short elsewhere, and where the mean duration of pre-stopping in long sonorants was significantly greater than the mean duration of pre-stopping in short sonorants. The Gupapuyngu and Warlpiri data would not support a reconstruction of the mean duration for pre-stopping in long sonorants greater than 30 ms. Consequently, even under this scenario, it is still necessary to posit that the change from a by-product realization to a production goal realization involved a lengthening of the pre-stopping component which would be independent of overall segmental length.

The distinction between production goal realizations and by-product realizations is similar to, but not the same as the distinction between contrastive and non-contrastive realizations. However, there are constraints on the potential relations between these two parameters, as set out in Table 19.

Table 19 Possible types of pre-stopping and their perceptual motivations

	By-product	Production goal
Non-contrastive	(A) /ˈka.n̪a/ → [ˈka(d̪)n̪a] Enhance place cues for nasals (pre-stopping highly variable)	(B) /ˈka.n̪a/ → [ˈkad̪n̪a] Predictable augmentation of phonologically strong position
Contrastive	–	(C) /ˈkad.n̪a/ → [ˈkad̪n̪a] Non-predictable augmentation of phonologically strong position

By definition, contrastive pre-stopping could not involve by-product realizations, but production goal realizations could be either contrastive (Type C) or non-contrastive (Type B). We suggest that the initial change in pre-Arabana was for non-contrastive pre-stopping to change from Type A to Type B. We suggest that then it became contrastive, i.e. a change from Type B to Type C. There are two factors which are likely to have been relevant in the change from Type B to Type C. We suggest one factor was loan words from Arandic varieties, which introduced pre-stopping into non-predictable positions in pre-Arabana. We suggest that the other factor was the complexity of conditionings on Type B in pre-Arabana.

As discussed in §2, there is a complex range of phonological and morphological factors affecting the distribution of pre-stopping in Arabana synchronically. Diachronically, increases in the duration of oral closure are central to the development of pre-stopping in Arabana. We consider here three factors which are known synchronically to constrain the distribution of lengthening. We suggest that these factors are also relevant to the diachrony of pre-stopping in Arabana.

(26) (a) A dispreference for lengthening in high frequency words
(b) A dispreference for lengthening in longer words—four or more syllables
(c) A dispreference for triple sequences of [-consonantal]

The higher the frequency of a morpheme, the more likely it is to be affected by phonetic reduction processes (Bybee 2006: 714–715). Given this, the converse may reasonably be posited, i.e. that higher frequency morphemes will resist lengthening processes that affect otherwise phonologically equivalent, but lower frequency, morphemes. Given further that grammatical morphemes tend to be higher frequency and most lexical morphemes tend to be lower frequency, this will approximate to the grammatical vs lexical division.

The research literature on the relationship between word length and segmental duration is not entirely consistent. Krull (1990) reports that increasing word length correlates with shorter segmental duration in Estonian. Lehiste (1970: 40–41) reports that in some languages overall word duration appears to be relatively constant. Consequently, in longer words, segments are of shorter durations. However, Nakatani *et al.* (1981: 89–90) report that word length did not correlate with shorter segmental duration in their study of American English. Quené (2008) reports that increasing phrase length correlated with decreasing segmental duration in Dutch. By contrast, Jacewicz *et al.* (2010) report that decreasing phrase length correlated with decreasing segmental duration in American English. Yuan *et al.* (2006) examined conversational telephone corpora of Chinese and English. For both languages, they report as utterances increased from one to seven words in length, possibly containing up to 13–14 syllables, there was a correlation with decreasing segmental length. However, this correlation did not continue for utterances of eight or more words.

This phonetics research literature does not address the variable of morpheme frequency. Inclusion of this variable might assist in resolving apparent conflicts. Jacewicz *et al.* (2010) note that reduction in segmental duration appears to relate to the degree of planning for morphologically and/or syntactically complex sequences. That is, monomorphemic words involve little planning, while phrases involve considerable planning, and planning in morphologically complex words will depend on how lexicalized the morphologically complex word is. Sequences with greater pre-planning are produced as continuous sequences with few or no pauses, and segmental reduction is more likely. By contrast, sequences with lesser pre-planning are much more likely to involve pauses, and segmental reduction is less likely.

In Pama-Nyungan languages generally, longer words are usually produced without pauses, and complex words of eight or more syllables are infrequent. There is no evidence which suggests that the production of Arabana departed from either of these norms. Therefore, it is reasonable to posit that longer words, which were usually multi-morphemic words, would have resisted lengthening and consequently pre-stopping. The same constituents when in shorter, single-footed words, would not have resisted lengthening realized as pre-stopping.

In combination, the factors in example (26) would produce a situation where pre-stopping would be found in post-tonic position for singleton consonants in lower frequency morphemes, usually lexical roots, when these morphemes were in shorter word forms: i.e. either unsuffixed or with only monosyllabic suffixes. In other environments, pre-stopping would be absent: higher frequency, commonly grammatical morphemes, post-tonic clusters, longer words. Under this distribution of pre-stopping, the forms of lexical roots would vary depending on morphosyntactic environment. This is illustrated in example (27), with constructions involving the pre-Arabana lexical root *mala 'dog'.

(27)	Unaffixed	'dog.ABS'	*mala*	[(madla)]
	Monosyllabic suffixation	'dog-DAT'	*mala-ku*	[(madla)-ku]
	Polysyllabic suffixation	'dog-DUAL'	*mala-pula*	[(mala)-(pula)]
	Endocentric compound	'dog nose'	*mala-mila*	[(mala)-(mila)]
	Reduplication	'doggie'	*mala-mala*	[(mala)-(mala)]

Diachronically, a change where the form of the lexical root found in simplex words spreads into complex word forms is highly likely, with the result that the morphosyntactic conditioning no longer holds and contrast develops. This change is particularly favoured in endocentric constructions, as the semantic match between independent and constructional occurrences motivates a phonological match: e.g. *mala-mila 'dog nose' > *madla-midla*. Synchronically in Arabana, endocentric constructions require a match in pre-stopping between independent and constructional occurrences of lexical roots.

The situation with exocentric constructions is less straightforward. The lack of a clear semantic match between independent and constructional occurrences reduces the motivation for phonological match between independent and constructional occurrences. The greater the degree of non-compositionality, the greater the opportunity for the development of phonological mismatches between independent and constructional occurrences.

There is also the conflict between metrical and morphosyntactic headedness to be considered. In Arabana, the metrical head is the left constituent, but morphosyntactically Arabana is right-headed. This allows for matching of either the metrical head or the morphosyntactic head or both or neither to independent occurrence. It is therefore unsurprising that exocentric constructions, both compounds and reduplications, show considerable variation in the distribution of pre-stopping.

7. Conclusion

Pre-stopping in Australian languages is a phenomenon of general phonetic and phonological interest, because it departs from the preferred cross-linguistic patterning for manner relations in [+consonantal] sequences. Cross-linguistically, the preferred ordering in coda clusters and heterosyllabic clusters is [sonorant][obstruent], as formalized in the SSG and SCL. The preferred order in onset clusters is [obstruent][sonorant], as also formalized by the SSG. However, onset clusters involving greater sonority distance are preferred over onset clusters involving lesser sonority distance (Clements 1990: 304). Consequently, [Stop][Liquid] onset clusters are preferred over [Stop][Nasal] onset clusters. Among Australian languages in which onset clusters are allowed, heterorganic [Stop][Liquid] onsets are preferred (Dixon 2002: 654). The appearance of [Stop][Lateral/Nasal] sequences as contrastive heterosyllabic clusters in Arabana departs from these norms.

For Arabana, we propose that this departure arose historically from a change in the status of pre-stopping productions, from being the by-products of other production goals to being goals of production in and of themselves. We propose that pre-stopping as a goal of production was initially non-contrastive. However, the operations of standard change processes have rendered pre-stopping contrastive in Arabana, though with a quantitative distribution across word structures that still matches closely to its original non-contrastive distribution.

Our analysis of pre-stopped sequences as heterosyllabic clusters in Arabana compared to their analysis as complex segments in Kaytetye necessarily raises a question as to the range of possible phonological analyses of contrastive pre-stopping. It also provides new materials against which theories of the complex segment as a construct may be evaluated.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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Appendix A: Arabana Headwords Elicited, Dataset 1 (Speaker Sydney Strangways [SS])

Headword	Definition	Notes
ORAL STOPS		
putu	dish, coolamon	
kata	head louse	
mathapurda	old man	
pithi	to glue	
puthurru	dust	
apalka	dream	
waparnda	to hunt, to seek	
thupu	smoke	
mupu	stick, piece of wood	
ipi-ipi	sheep	
kupula	intoxicating drink, grog	
mapaarnda	to sit together	SS corrected from *maparnda*
PLAIN LATERALS		
thililja	rose-bush, thorny acacia	*thi**d**lilja* in Arabana lexicon
mulurru	drizzle, very light rain	*mu**d**lurru* in Arabana lexicon
kala-rrantja	bicycle lizard	SS corrected from *karlantji*
thalarra-marnda	to frighten, to fight	SS rejected *waltha-marnda*

(*Continued*)

Appendix A: Continued

Headword	Definition	Notes
alhakiya	we two, father and child	
PLAIN NASALS		
punu	dirt, loose soil	*pudnu* in Arabana lexicon
anari	this way, towards us	
ininta	red bean tree	
munhunhu	maggot	
anhaku	I don't know	
mamarnda	to take away, to grab	
PRE-STOPPED LATERALS		
madla[2]	dog	
madlanti[2]	bad person, drunkard	
madla-yari	Stuart's pea	
mudlu-warlpu	backbone, spine	
mudluwaru	a shield	
kudluwa	needlewood plant	
kadlara	cloud	Spontaneously supplied by SS
pudlu	serum, gravy	SS corrected from *pulju*
pudluku	bullock, cattle	SS corrected from *pudluka*
wadlampu	hungry, starving	SS corrected from *wadla-purru*
kudlhu	stream of water, bubbles	
PRE-STOPPED NASALS		
wadna	yam-stick	
wadnarda	to take off, to strip off	
kudnurduku	mist, distant rain	
wadnakani	carpet snake	
kadnanundi	scorpion	SS corrected from *kidni-thaka*
itnirri	ankle	SS corrected from *muku-thiri*
kadnhaardi	money	
kadnha[1]	stone, rock	
kadnha-pardi	tablelands grasshopper	
pudnhu	cinders, cold ashes	
idnhirnda	to be, to exist	
wabmarri	plain, plateau	
wabmaRa	wind	*wamaRa* in Arabana lexicon
wabma	snake	