Apical stops in Arabana: lenition and undershoot

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Abstract

Commonly in Australian languages, the apical stops /t, ʈ/ show undershoot in manner, involving rhotic realizations: [r, ɾ, ɽ, ɻ], and in place involving the sublaminal target in retroflexion resulting in [t] realizations of /ʈ/. In Arabana, the apical stops rarely undershoot to rhotics, but undershoot realizations of /ʈ/ as [t] are common. Lenition theories posit that undershoot correlates with reduced duration. Lenition theories differ as to whether they posit undershoot or duration as the defining characteristic of lenition. Arabana expands the theory testing space as the manner undershoot is associated with reduced duration, but the place undershoot is not.

Index Terms: apicals, Australian languages, lenition, rhotics, stops, undershoot

1 Introduction

Arabana is a highly endangered language of northern South Australia. It is analyzed as having a contrast between an alveolar stop /t/ and a retroflex stop /ʈ/ within the apical category (see Table 1 for the full phonemic inventory) [1]. Lenition of intervocalic stops is a widespread phenomenon in Australian languages, and the apical stops commonly lenite to taps [2], [3]. In addition to the two apical stops, Arabana is also analysed as having three rhotics: an alveolar tap /ɾ/, an alveolar trill /r/, and a retroflex approximant /ɻ/.

	lab	den	alv	rfx	pal	vel
stop	p	t̪	t	ʈ	c	k
nasal	m	n̪	n	ɳ	ɲ	ŋ
lateral		l̪	l	ɭ	ʎ	
trill			r			
tap			ɾ			
approximant	w			ɻ	j	

Table 1: *Phonemic inventory of Arabana in IPA adapted from* [1]. *Apical stops and rhotics in grey. There are four phonemic vowels*: /i, u, a, aː/.

Apicals only appear in word-medial positions in Arabana [1]. The five-way contrast in stops and rhotics, /t/ vs /ʈ/ vs /r/ vs /ɾ/ vs /ɻ/, is found only in post-tonic, intervocalic position, i.e. ˈ#(C)V_V. Prosodic prominence is word-initial in Arabana and the tonic vowel is always the first vowel. In other intervocalic positions, there is a four-way contrast: /t/ vs /ʈ/ vs /r/ vs /ɻ/. Oppositions between apical stops and rhotics in consonant clusters are highly restricted and we do not consider data from clusters here.

1.1 Aims

This paper has two aims. The first aim is to quantify the extent of manner lenition, where apical stops are realized as taps, in Arabana. The second aim is to examine the overall patterns of gestural undershoot in the production of apical stops in Arabana and consider their implications for general theories of lenition.

If the common Australian patterns of lenition operate in Arabana, then the hypothesis is that there should be substantial overlap in realization between /t/ and /ɾ/ (see discussion in [4]). Given that lenition also commonly involves approximant realizations, there could also be overlap between /ʈ/ and /ɻ/, and [1] notes overlap in the realization of the three rhotics. We report quantitative data on the production of apical stops and rhotics in inter-vocalic positions in Arabana and examine whether these hypotheses are supported.

Gestural undershoot has played an important role in the debates over general theories of lenition, and in particular the question of whether all phenomena termed ‘lenition’ constitute a coherent class or not [5]. Some analyses propose that there is a coherent class of lenition processes with the defining criterion that processes involving gestural undershoot are lenition processes [6]. Other analyses propose that the defining criterion for lenition is variation in duration, which is principally conditioned by prosody, such that stronger prosodic positions favor longer, fortis realizations and weaker positions favor shorter, lenis realizations [7], [8]. Both analyses propose a relation between shorter duration and gestural undershoot.

General theories of lenition consider undershoot only from the perspective of manner of articulation. However, undershoot is also a factor from the perspective of place of articulation for apicals. In articulatory terms, retroflexes are more complex than alveolars. Both alveolars and retroflexes require apical contact, but retroflexes in Australian languages also consistently involve a sublaminal gesture [9]. If the sublaminal gesture is not attained, then an alveolar articulation results.

The Arandic and Western Desert languages associated with the areas to the north and west of Arabana are reported to have an alveolar versus retroflex opposition. However, in these languages,there is considerable overlap in the realizations of the two phonemes [10], [11]. We examine the distribution of alveolar versus retroflex phonetic realizations for apical stops in Arabana, and consider the role of gestural undershoot in this distribution.

2 Methods

2.1 Datasets

The analysis reported here is based on two datasets. In both datasets, the stimuli were real words. Dataset 1 consists of recordings with a first-language speaker of Arabana, Mr Sydney Strangways who was born in 1932, made in two fieldtrips in July 2019 and September 2020. In each fieldtrip, Author 5 initially reviewed a draft runsheet of headwords (extracted from [12]) with Mr Strangways. A final list of target headwords was then created. Each headword was assigned a unique identifier and a visual stimulus in MS Powerpoint was created. The headwords were randomized for five separate recording sessions made on consecutive days. Recordings were made in quiet locations with a Zoom H5 recorder using its internal microphone. To yield sufficient tokens for our analyses each elicitation prompted six to eight tokens (i.e. 30-40 tokens across sessions per type/condition).

Dataset 2 consists of a less structured recording with another first-language speaker of Arabana, Mr Laurie Stuart, now deceased, who was born in 1913. These audio materials were originally recorded to accompany a set of Arabana teaching materials already in print [13]. In order to provide comparison data with Dataset 1, we extracted target words with the same structure as were recorded in Dataset 1

Datasets 1 and 2 consisted of 57 and 60 distinct headwords respectively. The datasets included the full range of flanking vowels However, as the stimuli were real words, it was not possible to quantitatively balance the sets of flanking vowels. The three vowels /a, i, u/ do not have an equal distribution in the Arabana lexicon. In a vocabulary of 2,142 headwords, the vowel distribution is as follows: /a/ 4214 (57%), /i/ 1732 (24%), /u/ 1419 (19%) [12].

We distinguish three prosodic positions for word-medial inter- vocalic apicals in Arabana.

#(C +) V + Onset 1 + V + Onset 2 + V + Onset 3 + V

As illustrated, Onset 1 is the post-tonic onset and Onsets 2 and 3 are progressively later in the word. Both datasets sampled all three prosodic positions, but sampling of the positions was not quantitatively balanced because real word stimuli were required.

2.2 Annotation procedure and word selection

All target segments were manually segmented and transcribed by two phonetically trained annotators in *Praat 6.0.43* with the same spectrogram settings (Frequency range = 0-8 kHz; Dynamic range = 40.0 dB, window length 0.005; mean intensity (db) overlayed). The annotators were provided with orthographic transcriptions of the target words, but the target segments were masked.

The phonetic transcription was based a set of acoustic criteria. Place opposition between alveolar and retroflex articulation was distinguished using two well-known acoustic correlates of retroflex articulation: lowering of F3 ([14], [15]); and/or convergence of F3-F2 on the proceeding vocalic segment. Taps and trills were identified spectrographically by the following criteria: (1) a reduction in the amplitude (dB) of waveform relative to the spectral envelope; (2) a corresponding drop in mean spectral energy (in dB); (3) loss or attenuation of formant visible in the spectrogram between 500–5000 Hz. Stops were distinguished from taps by clear evidence of significant closure duration, with or without release.

In Dataset 1, from a pool of 2791 tokens, annotators agreed on 2583 transcriptions (92.5%). In Dataset 2, from a pool of 351 tokens, annotators agreed on 335 transcriptions (95%). These agreed tokens are the basis for the following analysis.

3 Results & Analysis

3.1 Distribution of phonetic stop and rhotic realizations against the phonological manner opposition /stop/ vs /rhotic/

Table 2 shows the phonetic and phonological distribution of stops and rhotics in Dataset 1. There was a high degree of consistency between the blind phonetic transcription of the two annotators and the phonological analysis of the target segments in Arabana. Of the 462 target segments transcribed phonetically as stops [t, ʈ], 458 (99%) were realizations of phonological stops /t, ʈ/. Of 548 phonological stop tokens /t, ʈ/, 458 (84%) were realized by phonetic stops [t, ʈ]. There was considerable variation in the remaining 16% of phonological stop realizations: [ɾ, ɹ, ɽ, ɻ]. It may be noted that the set of phonetic rhotic realizations for both phonological stops and rhotics includes the alveolar approximant [ɹ], which does not correspond to an independent phonological category.

Phonological category		Phonetic realization		Token No	%
Stop	/t, ʈ/	Stop	[t, ʈ]	458	83.6
		Rhotic	[ɾ, ɹ, ɽ, ɻ]	90	16.4
Rho tic	/r, ɾ, ɻ/	Stop	[t]	4	0.3
		Rhotic	[r, ɾ, ɹ, ɻ]	1,444	99.7

Table 2: *Distribution of stops and rhotics in Dataset 1*

Table 3 shows the phonetic and phonological distribution of stops and rhotics in Dataset 2.

Phonological category		Phonetic realization		Token No.	%
Stop	/t, ʈ/	Stop	[t, ʈ]	87	91.6
		Rhotic	[ɾ, ɻ]	8	8.4
Rhotic	/r, ɾ, ɻ/	Stop	[t]	2	1.5
		Rhotic	[r, ɾ, ɹ, ɻ]	132	98.5

Table 3: *Distribution of stops and rhotics in Dataset 2*

The same observation holds for Dataset 2 as for Dataset 1, with 87 of 89 (98%) of phonetic stop tokens being realizations of phonological stops, and 87 of 95 (92%) of phonological stop tokens being realized by phonetic stops.

3.2 Distribution of rhotic realizations of phonological stops by prosodic position

As discussed, we distinguish three prosodic positions for word-medial inter- vocalic apicals in Arabana. Onset 1 is the post-tonic onset and Onsets 2 and 3 are progressively later in the word. There was not sufficient data in Dataset 2 to evaluate the correlations between prosody and rhotic realizations and consequently we report only on Dataset 1 here. Table 4 sets out the distribution of stop and rhotic realizations for stop phonemes by prosodic position in Dataset 1.

	Stop realizations		**Rhotic realizations**	
	No	Percentage	No	Percentage
Onset 1	324	93.1	24	6.9
Onset 2	125	70.6	52	29.4
Onset 3	9	39.1	14	60.9

Table 4. *Distribution of stop and rhotic realizations by prosodic position in Dataset 1*

Overall, rhotic realizations are minority realizations (16%) for stop phonemes in Dataset 1. As Table 4 shows this minority realization pattern is not evenly distributed. Rather, the weaker the prosodic position, the more likely it is that an apical stop phoneme is produced phonetically as a rhotic.

3.3 Duration of phonetic stop realizations by prosodic category

There was a significant durational contrast between phonetic stop realizations in Onset 1 and Onset 2 positions, as set out in Figure 2. There was not sufficient data to evaluate Onset 3.

Figure 2: *Phonetic stop realizations in Onset 1 & 2*

The duration measures were selected as the dependent variable and fitted with a general linear model in *R* [16]. Onset conditions and speakers (as in different datasets) were fixed factors. There were significant main effects of onset conditions ($F = 119.98$, $df = 1$, $p < 0.001$) and speakers ($F = 81.86$, $df = 1$, $p < .001$) and a significant onset × speaker interaction ($F = 5.24$, $df = 1$, $p = 0.02$).

To further examine the phonetic categories effect, we ran pairwise multiple comparisons with Tukey adjustments for the phonetic category differences. Stops had longer durations than taps for both dataset (dataset 1: $\beta = 0.02$, $SE = 0.002$, $t(505) = 10.85$, $p < 0.001$; and dataset 2: $\beta = 0.011$, $SE = 0.004$, $t(505) = 2.76$, $p = 0.03$).

3.4 Distribution of alveolar vs retroflex phonetic stop realizations as against the phonological alveolar vs retroflex stop categories

Table 5 sets out the distribution of alveolar and retroflex stop realizations for Dataset 1 and Dataset 2.

	[t]		[ʈ]	
	No	Percentage	No	Percentage
Dataset 1				
/t/	259	100		
/ʈ/	150	75.4	49	24.6
Dataset 2				
/t/	16	100		
/ʈ/	56	78.9	15	21.1

Table 5: *Alveolar vs retroflex stop realizations of alveolar vs retroflex stop phonemes*

In both datasets, retroflex stop realizations are a minority phenomenon, 49 of 458 (11%) of total stop realizations in Dataset 1 and 15 of 87 (17%) of total stop realizations in Dataset 2. In both datasets, [ʈ] realizations are found only with the /ʈ/ segment and even with the /ʈ/ segment, they are a minority phenomenon, constituting 20–25% of /ʈ/ realizations.

There was variation between the two datasets in type–token relations for [ʈ] tokens. In Dataset 1, the 49 [ʈ] realizations were found with only four word types: *kaʈijapu* 'head', *kuʈa-ɳʈa* 'lie-PRES', *ŋuʈi-ɳʈa* 'halt-PRES', *ɲampaʈa-ɳʈa* 'cover-PRES'. In Dataset 2, the 15 [ʈ] tokens were found with 8 word types.

There was no significant difference in duration between the alveolar stop and retroflex stop phonetic realizations of the phonological retroflex stop.

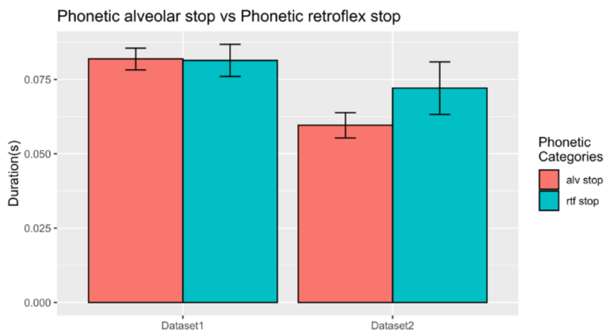

Figure 3: *Durations of phonetic alveolar stop and phonetic retroflex stop of the phonological retroflex stop*

The duration measures were selected as the dependent variable and fitted with a general linear model in *R* [16]. Manner of articulation and speakers (as in different datasets) were fixed factors. There is a significant main effect of speakers ($F = 48.29$, $df = 1$, $p < .001$) but no significant main effect of manner of articulation nor manner of articulation × speaker interaction.

4 Discussion

The two datasets show close agreement. In both datasets, there is a strong association between the phonetic and phonological stop categories, as summarized in Table 6.

	Dataset 1	Dataset 2
[t, ʈ] as realizations of /t, ʈ/	99%	98%
/t, ʈ/ realized by [t, ʈ]	84%	92%

Table 6: *Phonetic and phonological stops*

In both datasets, phonetic stop realizations in the post-tonic Onset 1 position are longer than phonetic stop realizations in the later Onset 2 position. In Dataset 1, where there was sufficient data to evaluate the correlations between prosody and rhotic realizations, 66/90 (73%) of rhotic realizations of phonological stops occur in Onset 2 and 3 positions. Overall, there is an association between stronger prosodic positions, greater probability of stop realizations, and longer duration of stop realizations. Conversely, there is an association between weaker prosodic positions, greater probability of rhotic realizations, and shorter duration of stop realizations.

Unlike the manner opposition between stop and rhotic, the alveolar versus retroflex place opposition did not show a clear match between phonetic and phonological categories. In both datasets, the retroflex stop [ʈ] was found only as a realization of /ʈ/. However, [ʈ] constituted only 20–25% of stop realizations of /ʈ/, with the bulk of stop realizations of /ʈ/ being [t], as summarized in Table 7.

	Dataset 1	Dataset 2
/ʈ/ realized by [t]	75%	79%
/t/ realized by [ʈ]	0%	0%

Table 7*: Realizations of apical stops by place*

There is one divergence between Datasets 1 and 2 relating to type–token relations for /ʈ/. In Dataset 1, the 49 [t] tokens related to only four word types whereas in Dataset 2, the 15 [t] tokens related to eight word types. This suggests that there may be significant inter-speaker variation in Arabana in the distribution of [t] realizations across type–token relations. Further, there may be significant inter-speaker variation in the comparative frequencies of [t] and [ʈ] as realizations of /ʈ/.

5 Conclusions

Theories of lenition posit a correlation between shorter duration and gestural undershoot but differ as to whether variation in duration or undershoot is the defining characteristic of lenition. Apical stops in Arabana show variation in both manner and place of articulation. Both types of variation involve undershoot. In terms of manner, the rhotic realizations of phonological apical stops can be modelled as a failure to attain the complete closure required for a phonetic stop realization. In terms of place, the alveolar realizations of the phonological retroflex stops can be modelled as a failure to attain the additional sublaminal gesture which distinguishes retroflexes from alveolars.

If undershoot is the defining characteristic of lenition, then both the rhotic realizations of the apical stops and the alveolar realizations of retroflex stops would class together as examples of lenition. However, it is only with the manner variations that undershoot correlates with shorter duration. For the place variations, alveolar realizations are not shorter than retroflex realizations. If variation in duration is the defining characteristic of lenition, then the manner variations are examples of lenition, but the place variations are not.

A full evaluation of undershoot vs. variation in duration as a basis for a category is beyond the scope of this paper. However, we note that analyses which take variation in duration as the criterion for category membership can encompass a wide range of phenomena extending beyond the traditional category of lenition to also include the traditional counterpart category of fortition [5], [7], [8]. By contrast, analyses taking undershoot as the criterion for category membership do not currently appear to encompass phenomena beyond undershoot. Given that analyses based in variation in duration appear to encompass a wider range of phenomena, they are favored, and we analyze the manner variations found with apical stops as lenition, but not the place variations.

Given this definition of lenition, apical stops in our Arabana data depart from typical patterns reported for Australian languages in showing only minimal lenition. The extent to which the patterns in our data are typical of Arabana more generally is a topic for further research. There are field recordings involving a number of other first language speakers of Arabana. These materials are not experimental materials and are generally similar in structure to Dataset 2.

These materials would also support further investigation into the nature of variation in the realization of retroflexion in Arabana. Our Arabana data on the apical place opposition was similar to that reported for the Arandic and Western Desert languages to the north and west in that there was no consistent match between phonetic and phonological categories [10], [11]. However, our Arabana data differed from that reported for the Arandic and Western Desert languages in that the inconsistency in matching was unidirectional. In Arabana, /ʈ/ commonly has [t] realizations, but /t/ does not have [ʈ] realizations. By contrast in the Arandic and Western Desert languages while /ʈ/ may have [t] realizations, /t/ may also have [ʈ] realizations.

A more general topic for further research is the extent to which lenition does and does not operate among Australian languages. Research on lenition in Australian languages has focused on contexts which satisfy the general phonological requirements for lenition and where lenition is commonly attested. There has been little investigation as to whether there are systematic correlates to the presence of lenition as a common phenomenon in these contexts. Equally, there has been very little investigation of situations where the general phonological requirements for lenition are satisfied but lenition is rarely attested. A better understanding of the comparative quantitative distribution of lenition from a cross-linguistic perspective is central to advancing theories of lenition.

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