VOICE ONSET TIME AND CONSTRICTION DURATION IN WARLPIRI STOPS (AUSTRALIA)

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ABSTRACT

This paper presents a first detailed analysis of the Voice Onset Time (VOT) and Constriction Duration (CD) stops /p t ʈ c k/ and flap /ɽ/ in the Indigenous Australian language Warlpiri as spoken in Lajamanu Community, in Australia's Northern Territory. The results show that Warlpiri stops are realised as voiceless, long-lag stops word-initially, as well as word-medially, where /p t k/ are also characterised by CDs in excess of 100 ms, similar to those reported for Kriol, and for the emerging mixed language Light Warlpiri, also spoken in the community, and by some of the participants. The results indicate that the realisation of word-initial Warlpiri flap /ɽ/ is highly variable, potentially resulting in a near-merger with the rhotic approximant /ɻ/. The results further suggest that Warlpiri does not make a word-medial distinction between stops orthographically represented by 'rt' and 'rd', which have been argued to be realised as /ʈ/ and /ɽ/, respectively.

Keywords: Warlpiri, stop consonants, Australian languages, VOT, constriction duration.

1. INTRODUCTION

The Australian Indigenous language Warlpiri is a Pama-Nyungan language spoken by approximately 2500-3000 people, including in the Indigenous communities of Yuendumu, Lajamanu, Nyirrpi and Willowra. Warlpiri is typically described as consisting of several regional dialects [1, 2], though it is possible that present-day community configurations may have resulted in changes to previously reported dialect distinctions. Noteworthy also is a partial language shift in one community, where a new mixed language, Light Warlpiri, has emerged [3]. Light Warlpiri incorporates elements of varieties of English as well as Kriol, a creole spoken widely in the Northern Territory [4]. The phonological system of Warlpiri is described as sharing many similarities with other Australian Indigenous languages; it consists of just three vowels (/i a u/); a single series of stops /p t ʈ c k/ with five main places of articulation, and an absence of fricatives. It is also described as having three rhotic phonemes; trill /r/, approximant /ɻ/, and a retroflex flap /ɽ/ [5], which, apart from an absence of build up of air-pressure resulting in a distinct release burst, is articulatorily similar to a /ʈ/. The phonetics of Warlpiri have received relatively little attention, with the exception of early impressionistic descriptions [5] and more recently small-scale studies of Warlpiri phonetics with particular focus on intonation [6], allophonic variation in voicing [7], and inter-speaker variation in the realisation of the word-initial realisation of the rhotic flap /ɽ/, orthographically represented in as 'rd' [1]. We present a first systematic acoustic analysis of the VOT and CD of stops in Warlpiri as spoken in the Lajamanu Community. The analysis is presented in two parts: *Section 3.1* presents the Voice Onset Time (VOT) of word-initial stops /p t c k/, and an analysis of variation in word-initial /ɽ/, while *Section 3.2* presents VOT and Constriction Duration (CD) data from word-medial stops and flap /p t ʈ ɽ c k/ (including discussion of variation in the realisation of medial /ɽ/ and differentiation of medial /ʈ ɽ/ in *Sections 3.2.3* and *3.2.4*, respectively).

2. PARTICIPANTS AND MATERIALS

Six female speakers of Warlpiri participated in the study. Two were speakers of Warlpiri only (WO) both in their late 40s, while four participants spoke both Warlpiri and Light Warlpiri (W+LW): two in their late teens; one in her early 20s; and one in her 30s. The participants thus may represent two different generations and language-use profiles, and their data will be presented separately in the analyses, so as not to obscure potential language change. All participants were literate in Warlpiri and English, and spoke English as a second language. The participants read an average of five or six repetitions of a list of 33 Warlpiri words. Initial targets were extracted from: *jaja, jaka, jilimi, jipilyaku, jitimi, jungarni, jupurrurla, kardiya, karnta, kartirdi, kata, kiwinyi, kurdu, kuyu, pajirni, pintaru, purla-purla, purlapa, tari, timana, tiya-tiya, turlturrpa, tururru, rdaka, rdilyki, rduku-rduku*; medial targets were extracted from *jaja, jaka, kata, kurdu, luku, lupu, mirdi, ngapa, rdaka,* and *wati*, as well as *mukarti* and *kartirdi*. All target words were

two-four syllables long (only the first target in reduplicated words *purla-purla* and *rduku-rduku* were extracted), and on the basis of existing descriptions of Warlpiri stress, all were assumed to have primary stress on the first syllable [5], potentially resulting in post-tonic stress on the second syllable (see discussion in [8]). All targets were elicited in a Warlpiri carrier sentence (*ngaju karna ___ wangkami:* 'I'm saying ___'), presented on a computer monitor in a self-paced reading task. Recordings took place in the Batchelor Institute for Indigenous Tertiary Education Learning Centre, in the presence of the second author and other Warlpiri speakers. The target words elicited all Warlpiri stops and the flap in word-initial position (/p t ʈ c k/) as well as word-medial position (/p t ʈ ɽ c k/). Note that the /t ʈ/ distinction is neutralised word-initially [5, 8, 9]. The phone is conventionally transcribed as <t>, despite impressionistic descriptions as [t̪] [9]. See also discussion of medial /ʈ ɽ/ in *Section 3.2.4*. All recordings had a 16-bit sampling depth with a sampling rate of 44.1 KHz.

3. RESULTS

3.1. Initial stops

3.1.1. VOT in word-initial stops (excluding /ɽ/)

The recordings yielded 831 tokens from which initial VOT could be extracted. A small number of additional tokens were excluded from analysis due to environmental noise (dogs, doors slamming, fans, etc.). The six participants contributed evenly to the dataset (133-150 tokens/speaker), and the distribution of the phonemes was relatively even (148 /p/; 178 /T/; 251 /c/; 254 /k/). The initial VOT results (see *Figure 1*) show that Warlpiri stops /p t c k/ are produced as long-lag voiceless stops. Visual inspection (of qqplots) indicated that the Warlpiri data was not normally distributed, and we transformed all duration measurements using log10(duration+1). We conducted an LMER, with 'consonant' as fixed factor, and 'speaker' as random effect, which indicated that VOT in word initial position differed significantly. Post hoc comparisons between all stops indicated that all stops differed in VOT (*df* 822; $p < .001$ in all cases). The pattern in VOTs is largely consistent with a (universal) tendency for VOT to increase as a function of degree of POA 'backness', though see discussion of VOT of alveolar and retroflex stops in *Section 4*. There was no significant effect of 'group' (WO vs. W+LW), suggesting that the two groups of speakers produce similar VOT in word-initial position.

3.1.1. Variation in word-initial /ɽ/

A total of 115 tokens of word-initial /ɽ/ were extracted from target words *rdaka*, *rdilyki*, and *rduku-rduku*, selected to provide balanced vowel environments. Fine-grained phonetic analysis suggested the identification of five realisations of /ɽ/: [ɻ], [ɻɾ], [ɽɾ], [lɽ], and [ɽlɽ]. *Table 1* provides a summary of the distribution of the five realisations by the three target words and indicates that across speakers, [ɻ] was the most likely realisation. We did not characterise any /ɽ/ as trills [r] due to the clearly identifiable burst(s) and relatively long [ɻ] elements (sometimes in excess of 100 ms). Analysis of individual modal productions suggest that the two WO speakers and one of the four W+LW speakers used [ɻɾ] as their modal realisation, while two other W+LW speakers used [ɽlɽ] as their modal realisation, and the final speaker used [ɻ] in 23 out of 24 cases. All speakers used at least two realisations.

Figure 1: Mean initial VOT in ms by speakers of Warlpiri and Light Warlpiri (4; LW+W) and Warlpiri only (2; WO). Error bars reflect SD.

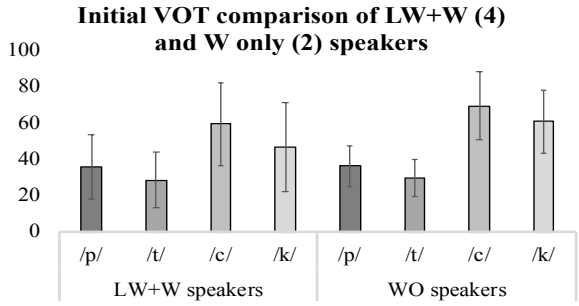


Table 1: Distribution of the five realisations of word-initial /ɽ/ across three target words.

	[ɻ]	[ɻɾ]	[ɽɾ]	[lɽ]	[ɽlɽ]	N	Modal
rdaka	19	16	2			**37**	**[ɻ]**
rdilyki	9	11	3		12	**35**	**[ɽlɽ]**
rduku	17	13		1	12	**43**	**[ɻ]**
Total	**45**	**40**	**5**	**1**	**24**	**115**	

3.2. Word-medial VOT and Constriction Duration

The recordings yielded a total of 361 disyllabic Warlpiri words with a CVCV structure. We limited the analyses to CVCV words to avoid potential effects of 'position in word', as Warlpiri stops have been described as decreasing in duration as a function of 'position in word'. It is not clear, however, that this is a consistent effect, nor clear that it affects VOT as opposed to, for instance, CD [6]. (For a discussion of 'position in word'-effects in the present study, see *Section 3.2.4*). As in the word-initial dataset, the six participants contributed evenly

to the dataset (16-17%/speaker), and the distribution of phones in the dataset was relatively even (71 /p/; 73 /t/; 74 /ɽ/; 107 /k/), with the exception of /c/ (36 tokens only). 318 of the stops were realised with a clear constriction period followed by a release burst, allowing the extraction of both CD and VOT information. 43 of the 74 /ɽ/ tokens were realised as flaps, and thus yield only one durational measure. Medial /ɽ/ is discussed in *Section 3.2.3*. As there were no cases of second syllable onset /ʈ/ in the CVCV targets, 74 tokens of /ʈ ɽ/ from the onset of the third syllable are discussed in *Section 3.2.4*.

3.2.1. VOT in word-medial stops

The medial VOT results (*Figure 2*) are consistent with the initial VOT data, and also suggest that Warlpiri stops /p t c k/ are produced as long-lag voiceless stops (see discussion of /ɽ/ in Section 3.2.3). The medial VOT measurements were not normally distributed (visual inspection of qqplots), and we transformed all duration measurements using log10(duration+1). A LMER with 'consonant' as fixed factor and speaker as a random effect was significant ($p < .001$). Post hoc comparisons revealed that the VOT of /k/ did not differ from that of either /p/ or /c/ in medial position, while all other stops differed in VOT ($p < .001$ for all, except /t/ versus /ɽ/: $p = .02$, and /c/ versus /p/: $p = .0032$).This is, again, generally consistent with VOT duration increasing as a function of POA 'backness'. Consistently with the initial VOT results, there was no effect of 'group', indicating that the word-medial VOTs of WO and W+LW speakers do not differ.

3.2.2. CD in word-medial stops

The medial CD results (*Figure 3*) suggest that Warlpiri stops /p t k/ are realised with a medial constriction duration well in excess of 100 ms, similar to the range reported for fortis stops in some Indigenous Australian languages which have a fortis-lenis stop distinction [10], as well as that reported for the voiceless series of stops in Kriol [4]. The CD data was, again, not normally distributed (on the basis of visual inspection of qqplots), and we transformed all duration measurements using log10(duration+1). A LMER with 'consonant' as fixed factor and speaker as random effect was significant ($p < .001$). Post hoc comparisons revealed that all stops differed from each other in terms of CD ($p < 0.001$ for all, except /c/ vs. /p/: $p = .015$) and /p/ vs. /t/: $p = .017$), with the exception of /k/ vs. /p c/, and /t/ vs. /ɽ/. These results are consistent with an effect of increased 'backness' resulting in longer CDs, though the fact that stops /ɽ/ and /c/ are produced with much shorter CD than other stops deserves some discussion. In the case of /ɽ/, this is consistent with the medial VOT results. It is less clear why /c/ does not follow the pattern of /p k/, and to some extent /t/, though it may be relevant that the speakers of Light Warlpiri maintain a VOT and CD contrast between /ʧ/ and /ʤ/ in words sourced from English and/or Kriol, and that the CD of /ʤ/ corresponds to that of /c/ in words of Warlpiri origin [11]. There was no effect of speaker group, indicating that the WO and W+LW speaking participants produce similar word-medial CDs.

Figure 2: Mean medial VOT in ms by speakers of Warlpiri and Light Warlpiri (4; LW+W) and Warlpiri only (2; WO). Error bars reflect SD.

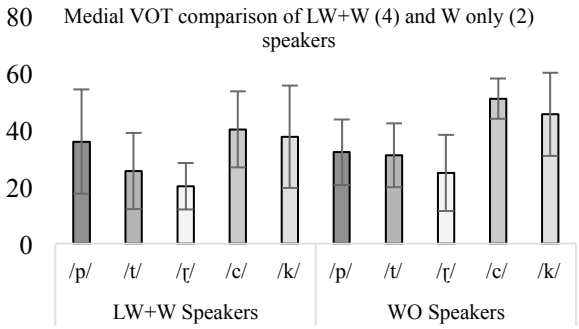
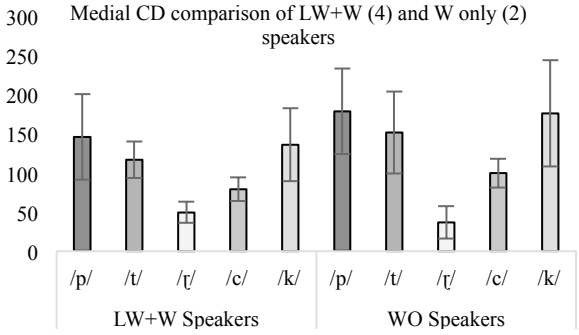


Figure 3: Mean medial CD in ms by speakers of Warlpiri and Light Warlpiri (4; LW+W) and Warlpiri only (2; WO). Error bars reflect SD.



3.2.3. Word-medial /ɽ/

The 74 instances of word-medial /ɽ/ (orthographic 'rd') were extracted from the target words *mirdi* and *kurdu*. The /ɽ/ targets were characterised by two realisations: a stop realisation [ʈ] with a mean (and quite short) combined VOT+CD duration of 65 ms (VOT and CD in *Figures 2* and *3*), and a tap [ɽ] realisation with a mean duration of just half of that at 28 ms. This contrasts with previous work that argues that medial 'rd' is realised as a brief retroflex tapping gesture [5]. *Table 2* provides a detailed breakdown of the pattern of /ɽ/ realisation. From this table, it is clear that /ɽ/ segments produced in a high-front vowel context /iCi/ are much more likely to have a 'full', temporally expanded, retroflex stop

realisation [ʈ] whereas /ɽ/ in the high back-vowel context /uCu/ is much more likely to be [ɽ], an allophony pattern which appears to be related to the distribution of the apical contrast reconstructed by Dixon [12]. We speculate that this is due to well-established articulatory difficulties in producing clearly retroflex targets in this environment: by expanding the stop realisation, a speaker/hearer may be able to more clearly differentiate /ɽ/ from, for instance, medial /t/.

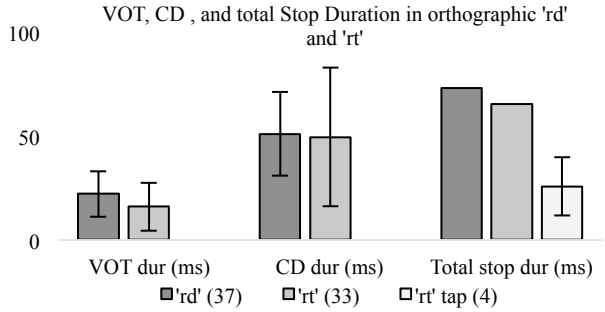
Table 2: Distribution and mean duration of 74 tokens of orthographic 'rd' in /uCu/ and /iCi/ contexts. The average duration of [ʈ] = CD + VOT. WO indicates Warlpiri-only speakers.

	/uCu/				/iCi/			
	/ɽ/		/ʈ/		/ɽ/		/ʈ/	
ID	**N**	**ms**	**N**	**ms**	**N**	**ms**	**N**	**ms**
A56 (WO)	6	39			3	42	3	82
A69 (WO)	6	20			3	19	3	41
AC09	4	32	2	50	1	23	5	51
AC41			6	76			6	77
AC58	7	25					6	78
A21	6	23			7	27		
Total N	**29**		**8**		**14**		**23**	
Total %	**78**		**22**		**38**		**62**	

3.2.4. Word-medial differentiation of /ʈ ɽ/

As is clear from *Section 3.2.3*, word-medial /ɽ/ has variable realisation. This may interfere with the maintenance of a phonological distinction between orthographic 'rd', traditionally describes as flap /ɽ/, and a orthographic 'rt', previously described as a retroflex stop /ʈ/. Since the CVCV data set did not include instances of orthographic 'rt' with which to compare the realisations of 'rd', we extracted 37 instances of both orthographic 'rt' and orthographic 'rd' from third-syllable onsets in *mukarti* and *kartirdi*. With the exception of four [ɽ]-realisations of 'rt' in the target word *mukarti*, all were produced as [ʈ], with distinct CD and VOT phases (see *Figure 4*), consistent with the mean CD and VOT reported for medial /ɽ/ realised as [ʈ] in CVCV context. Taken together with the variation in word-medial /ɽ/, this suggests that speakers of Warlpiri in Lajamanu do not contrast medial /ʈ/ and /ɽ/, and that variation in the realisation of a single Warlpiri retroflex stop /ʈ/ as either [ʈ] or [ɽ] depends in part on the vowel environment. There is no evidence from the present data set that position in word affects the realisation in such a way that stops become progressively shorter (or realised as flaps more frequently) the further they are from the onset following the primary-stressed first syllable (a pattern called *post-tonic lengthening*) [6, 8].

Figure 4: Mean VOT and CD of 'rt' and 'rd' in third syllable onsets. Error bars reflect SD.



4. DISCUSSION

The present study confirms that word-initial and -medial stops in Warlpiri are realised as long-lag/voiceless stops, with relatively long word-medial constrictions. The VOT and CD of Warlpiri stops generally follow the frequently observed pattern of increased durations as an effect of increased 'backness' in terms of POA, thought to have significant articulatory underpinnings. The notable exceptions to this pattern are the relatively short durations of the alveolar and retroflex stops, though this is to some extent consistent with what has been reported for other languages (see for instance a study of Indo-Iranian languages [13]). The study also reveals a great degree of variation in the realisation of word-initial /ɽ/, consistent with previous reports. Indeed, the high frequency of [ɻ] realisations of /ɽ/ may be a strategy to differentiate /ɽ/ from <t> (typically realised as [ʈ]). Further, this may potentially result in a near-merger of /ɽ/ with /ɻ/, though further acoustic analyses and perceptual testing is necessary to test this hypothesis. The study also indicates that there is no clear differentiation of /ʈ ɽ/ word-medially, suggesting that it may be the case that Warlpiri has just one retroflex stop /ʈ/, which has different allophonic realisations word-initially and word-medially. The present data does not provide evidence to support the claim that position in word has a strong effect on stop (VOT + CD) duration in Warlpiri, though the study was not designed to explicitly test this hypothesis. Finally, the fact that we did not observe any significant differences in the realisation of stop voicing between speakers of Warlpiri only (WO) and those younger speakers who also use Light Warlpiri (W+LW) suggests that the findings are consistent across these groups, despite generational differences and daily language use patterns.

7. REFERENCES

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