THE ARTICULATION OF CONTRASTIVE AND NON-CONTRASTIVE PRE-STOPPED CONSONANTS IN KAYTETYE

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ABSTRACT

Kaytetye is an Australian language with a unique combination of phonemic pre-stopping in its nasals series, as well as non-contrastive pre-stopping in its lateral series. In this paper, we describe two phonetic correlates of pre-stopping in Kaytetye, segmental duration and extent of tongue movement. With nasals, pre-stopped segments are longer and have greater tongue movement than their plain counterparts. Neither of these patterns holds for laterals. We interpret these differences in light of their phonemic status.

Keywords: speech articulation, ultrasound, coronal consonants, Kaytetye, Arandic language family

1. INTRODUCTION

Kaytetye is an Arandic language spoken by approximately 200 speakers, near Alice Springs, NT in Australia. Like many Australian languages, Kaytetye has an extensive consonantal inventory, outlined in Table 1[1].

As shown in Table 1, Kaytetye contrasts plain and pre-stopped nasals[2], which is unusual in Australian languages. While pre-stopping of both nasals and laterals is common in Australian languages, it is often not contrastive [3, 4], with its presence being subject to both inter- and intra-speaker variability. A feature peculiar to Kaytetye is the existence of both *contrastive* pre-stopping in nasals (as shown in Table 1) as well as *non-contrastive* (variable) pre-stopping in laterals [6].

In addition to differing in phonemic status, pre-stopped nasals and laterals differ in the relationship of their duration compared to the duration of their plain counterparts. [6] reports that pre-stopped nasals are longer than plain nasals (by approximately 60ms on average), and pre-stopped laterals are not significantly longer than plain laterals. Furthermore, duration of pre-stopping is significantly shorter in laterals than it is in nasals for Kaytetye speakers.

A reasonable hypothesis for the existence of these differences is that they are due to the phonemic status of the pre-stopped variant. That is, because plain and pre-stopped nasals are contrastive (e.g. /aˈnəɲɡə/ *sit* vs. /aˈᵗnəɲɡə/ *stand*), sufficient difference in their phonetic characteristics is required.

In this paper, we ask whether these differences extend to the physiological, in particular, to the lingual articulation of these consonants. We first establish what articulatory differences exist between the production of pre-stopped and plain nasals. We then ask whether these differences result from contrastiveness – that is, do they reflect the phonemic nature of pre-stopped nasals – or do they result from physiological characteristics inherent to the articulation of pre-stopping? Specifically, we expect if these differences are phonetic in nature that they will extend also to the lateral series, in which pre-stopping exists but is not contrastive.

	Labial	Dental	Alveolar	Retroflex	Palatal	Velar
Stop	p	t̪	t	ʈ	c	k
Nasal	m	n̪	n	ɳ	ɲ	ŋ
Pre-stopped Nasal	ᵖm	ᵗn̪	ᵗn	ᵗɳ	ᶜɲ	ᵏŋ
Lateral		l̪	l	ɭ	ʎ	
Tap			ɾ			
Continuant	w			ɻ		ɰ

Table 1: The phonemic inventory of Kaytetye

2. DATA COLLECTION AND ANALYSIS

2.1. Participants and procedures

The participants in this study were six female Kaytetye speakers, aged 38-62, who were residents of Stirling and Neutral Junction, NT. Participants engaged in an elicited imitation task, in a quiet room in Stirling, where they were presented with an im-

	Dental	Alveolar	Retroflex
Stop	aˈʈ̪əŋanəɲə	aˈtakə	aˈʈəŋanəɲə
	aˈʈ̪əŋə	aˈtəkə	aˈʈəpə
	aˈʈ̪əpə	aˈtəŋanəɲə	
Nasal	aˈn̪amənaʈə	aˈnamə	aˈɳenge
	aˈn̪apəʈə	aˈnəŋanəɲə	
PSN	aˈᵗn̪əpə	aˈᵗnamə	aˈᵗɳəŋə
Lateral	aˈl̪əkəɻə	aˈləkə	aˈɭəmənə
		aˈleme	aˈɭəpə

Table 2: Elicited and analyzed words, by place and manner of articulation. Target consonants bolded.

age depicting a target word and an audio prompt, pre-recorded by a native female speaker of Kaytetye. The audio prompts consisted of the carrier phrase [aŋkənəŋə X], or *Say X!*

Participants were then asked to repeat the utterance, while audio and ultrasound data from their speech were recorded. Audio was recorded using a Behringer C-2 condenser microphone connected to an M-Audio DMP3 preamplifier, and ultrasound video was generated using a Sonosite 180 Plus. The ultrasound probe was held manually by the experimenter under the participant's chin and angled to provide a sagittal view of the participant's oral cavity. Both ultrasound and audio were recorded onto a Sony mini-DV DCR-TRV103 digital camcorder, with the ultrasound video streaming at (NTSC standard) 29.97 fps.

2.2. Target stimuli

The target words contained the coronal nasals /n, ɳ, n̪, ɲ/, pre-stopped nasals /ᵗn, ᵗɳ, ᵗn̪, ᶜɲ/, and laterals /l, ɭ, l̪, ʎ/, all in a /#V_V/ context. The target coronal segments were preceded by word-initial /a/ and followed by a stressed /a/ or /ə/ (e.g. aᵗnə́mə *yamstick*). Table 2 enumerates all stimuli elicited and analyzed in this study. Note the absence of palatal consonants in Table 2 – while words containing palatal target consonants were elicited, many of the tongue contours during these constrictions were extremely difficult to see in the ultrasound images due to the distance between the tongue surface and ultrasound transducer. Thus palatal consonants were not analyzed in this study.

2.3. Acoustic and ultrasound analyses

The ultrasound videos were digitized in FinalCut Pro, and audio and frames were extracted for each target word repetition.sdf Praat [2] was used to mark the boundaries of the vowels surrounding the target consonant (/VCV/), and all frames between the
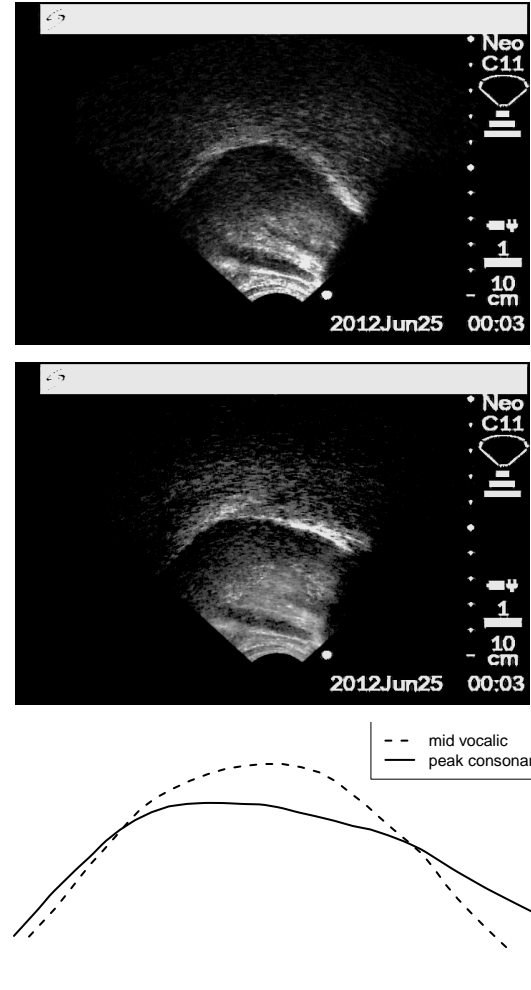

Figure 1: Vocalic (top) and consonantal (middle) frames from a production of aʈəŋə from speaker S03, with tracings from these contours (bottom).

onset of the vowel preceding and the offset of the vowel following the target consonant were extracted. At the same time, each utterance was also coded for whether the target consonant contained (acoustically) visible closure or not. Not surprisingly, nearly all pre-stopped nasal targets were produced with a period of stopping (154 of 158 items), and nearly all plain nasal targets were produced with no stopping (160 of 163 items).

Edgetrak [10] was then used to trace the visible tongue contour in each of these frames. Because no probe stabilization was used, the tongue contours were normalized against the frame at the midpoint of the preceding vowel. Specifically, for each utterance, a vocalic contour was defined, as the tongue contour in the frame closest to the acoustic midpoint of the vowel, as demonstrated in Figure 1. Then, for each target consonant, the degree of anterior tongue movement was calculated as the distance (mm) between the most anterior portion of the tongue con-

tour and the vowel contour. We note here that because no probe stabilization was used, it is plausible that, in some productions, the probe was repositioned between the midpoint of the vowel and the midpoint of the target consonant, generating noise in the data. The most obvious cases of these were not included in the data, and more detailed analysis of degree and acceptability of this movement is currently being undertaken.

3. RESULTS

All statistical comparisons in this section were made using linear mixed effects models, with Subject, Repetition, and Place of Articulation as random factors. Unless otherwise indicated, fixed factors were included as random slopes in the Subject random factor. Analyses were performed in R, using the lme4 package [1], and the lmerTest [9] package for p-values.

From [6], we expect that pre-stopped nasals should be significantly longer than plain nasals. In the subset of the data analyzed in this study, this continues to be true ($\beta = 0.0745, t = 5.79, p = 0.0022$). We therefore expect that, because speakers have more time to reach their articulatory targets, movement of the tongue towards the targeted place of constriction should be greater in pre-stopped nasals than in plain nasals. Indeed, as shown in Figure 2 (left), pre-stopped nasals have significantly more movement than plain nasals ($\beta = 2.00, t = 2.64, p = 0.0492$), confirming our expectations. This expectation is confounded, however, by the fact that plain and pre-stopped nasals are contrastive for Kaytetye speakers. That is, this difference in lingual movement may be a manifestation of different articulatory targets, rather than the relationship between speakers' ability to reach those targets and segmental duration.

We ask then, whether pre-stopping in the Kaytetye lateral series, which is not contrastive, can provide any insights. As shown in Figure 2 (right), unlike the nasal series, there is no significant difference in amount of tongue movement in pre-stopped laterals than plain laterals ($\beta = -0.47, t = -0.73, p = 0.5050$). One caveat is that presence of pre-stopping in laterals does not significantly increase the segmental duration ($\beta = -0.01, t = -1.48, p = 0.1970$), so while the behavior in amount of motion between pre-stopped and plain realizations differs between nasals and laterals, the implication does not – presence of pre-stopping has a significant effect on *both* segment duration and tongue movement for nasals, and it has no significant effect
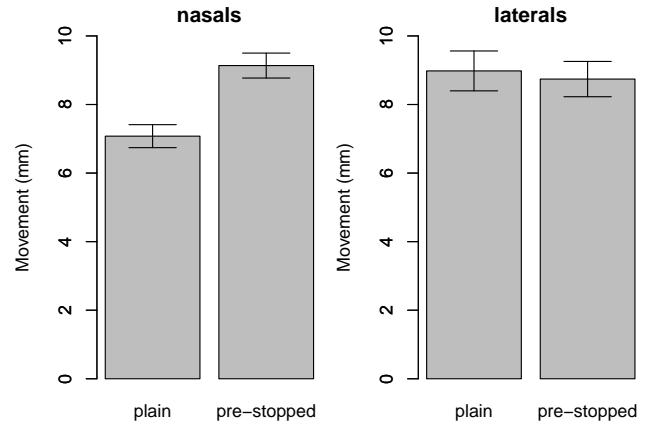

Figure 2: Movement of tongue tip / blade by presence of pre-stopping for nasals (left) and laterals (right)

on *either* in laterals.

Therefore, a model adding Segment Duration (ms) as a continuous fixed factor, in addition to existence of Pre-stopping, against the extent of tongue movement in laterals was run. A version of this model that included the interaction term (Duration x Pre-stopping) was also run, but model comparison found that this interaction was not significant ($\chi^2[2, 13] = 1.65, p = 0.1991$), so we report only the results from the first model, without the interaction term. In this model, presence of pre-stopping still demonstrated no significant effect on tongue movement, but segment duration did. On average, an increase in duration of 1 ms resulted in a 0.028 mm increase in tongue movement ($\beta = 0.028, t = 2.56, p = 0.0359$) in lateral production, regardless of whether pre-stopping was present. The analogous model, adding Segment Duration as a continuous factor to Pre-stopping for the nasal series could not be created, because the previous analysis showed that those factors are not independent; thus the factors could not be included simultaneously. Thus similar model, with Segment Duration (ms) replacing existence of Pre-stopping as a fixed factor, was also run on the nasals series, with similar results ($\beta = 0.018, t = 3.09, p = 0.0320$) to the laterals. These findings are illustrated in Figure 3. At the outset, this suggests that the differences in duration and lingual movement between plain and pre-stopped nasals may be solely phonetic in nature.

However, when run on the pre-stopped nasal and plain nasal series, separately, the effect of duration disappears ($\beta = 18.94, t = 1.74, p = 0.1363$ in the pre-stopped series, $\beta = 7.018, t = 0.397, p = 0.7120$). Figure 3 (left) differentiates the individual points by whether they belong to the pre-stopped or plain nasal series, and the mean values for each
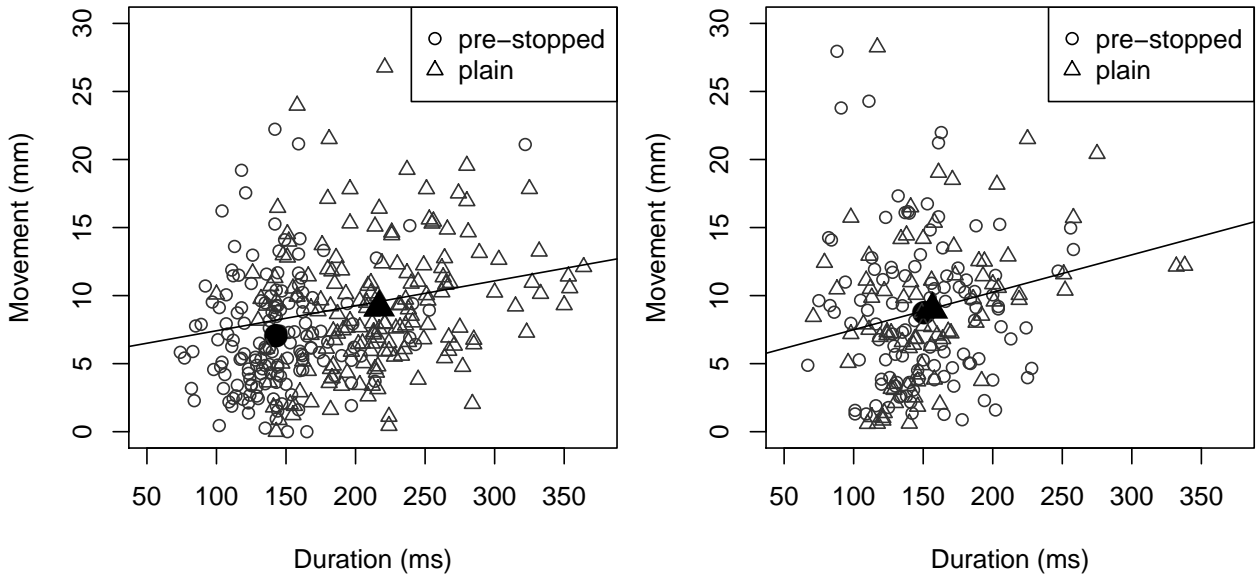
Figure 3: Movement of tongue tip / blade (mm) by segment duration (ms) in nasals (left) and laterals (right), with separate symbols for pre-stopped and plain productions. Best fit trendlines from the models are overlayed. Mean values for pre-stopped and plain productions in larger solid symbols.

phonemic category are also plotted, in larger filled in symbols. These data combined suggests that the effect between segment duration and tongue movement in the nasals is most likely a result of differences in the means of both segment duration and tongue movement between the groups. That is, because duration does not have a significant effect on tongue movement in either nasals or pre-stopped nasals, within category, the effect found previously, that duration and tongue movement are correlated in nasals, is most likely the result of independent tendencies of pre-stopped nasals to be both longer and exhibit more movement than plain nasals.

4. DISCUSSION

These findings suggest that, while there is a link between segment duration and degree of lingual movement, and by extension, strength of primary constriction, this link may have been severed, and these differences phonologized in the contrast between plain and pre-stopped nasals. In other words, we interpret our findings as showing a phonetic / physiological relationship that is evident in the lateral series, and which has become inherent to the phonetic encoding of contrastiveness of the pre-stopped vs. plain nasal series.

5. ACKNOWLEDGEMENTS

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[1] Following Harvey [5], we consider what Koch [8] and Turpin [14] regard as "prepalatal apical" series as a consonant sequence of /j/ + an apical alveolar consonant, rather than a coronal series in its own right [7]. These consonants therefore do not appear in this analysis

[2] We consider the question of whether Kaytetye pre-stopped nasals are pre-stopped nasals or stops with velic release [12] to be outside the scope of this study. We adopt the conventional stance that they are diachronically related to nasal stops (and not oral stops). [11, 13, 14]

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