THE PERCEPTION OF CORONALS IN WESTERN ARRERNTE

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ABSTRACT

This study examined perception of multiple coronal places of articulation by native listeners of Western Arrernte. Three main findings emerged. 1) Coronal nasals and laterals are as perceptually robust as coronal stops. 2) Across manners of articulation, apical alveolars are less perceptually robust than other coronals. 3) Formant transitions from a preceding vowel are necessary to correctly identify apical alveolars and apical postalveolars. Acoustic analysis shows the importance of cues on the preceding vowel side for apical postalveolars, and on the following vowel side for laminal palatoalveolars. Laminal dentals have statistically distinguishable cues on both sides of the segment. Apical alveolars are hardest to characterize acoustically, and may be perceived by default. Low perceptibility of apical alveolars may be a reason for low functional load of the apical contrast. Result 3 corroborates Steriade's idea that contrasts "must be licensed by the presence of their cues." [4]

1. INTRODUCTION

1.1. Background

W. Arrernte is spoken in an area west of Alice Springs, Central Australia. It is typologically rare among the world's languages in having a four-way contrast among coronal phonemes (those whose segments are articulated with the tip or blade of the tongue against the roof of the mouth.) These contrasts hold of stops, nasals, and laterals (see Table 1a. W. Arrernte also uses a set of contrastive pre-stopped nasals, \pm\, \t1n1\, \tn\, \t¢n¢\, \t2n2\, \kN\, which will not be treated here.) Coronal segments are usually described as "laminal dental", "apical alveolar", "apical postalveolar" and "laminal palatoalveolar." In W. Arrernte the two apical coronal places contrast intervocalically, but not initially (See Table 1b.) Moreover, even where the apical contrast exists, it has a lower functional load than other contrasts.

1.2. Goals and Hypotheses

A.) For non-native speakers of W. Arrernte, coronal place distinctions are notoriously difficult to hear, especially in the nasals and laterals. The first goal of this study was to determine whether these difficulties are due simply to non-native listeners' lack of experience in listening for the contrasts, or to inherent relative weakness of cues among contrasts. Thus, the first task was to determine the reliability with which native listeners can differentiate among coronal stops, coronal nasals and laterals, without the benefit of context. We hypothesized that A1) Like non-natives, native listeners would differentiate more easily among stops than among nasals or among laterals. A2) Given the lower functional load of the apical contrast, alveolar and postalveolar segments would be less perceptually robust than other coronal place contrasts.

Table 1a: W.Arrernte stops, nasals, laterals

		Coronal places of articulation				
	Bilabial	Laminal Dental	Apical Alveolar	Apical Post-alveolar	Laminal Palatoalveolar	Dorsal Velar
Stops	p	t1	t	t¢	t2	k
Nasals	m	n1	n	n¢	n2	N
Laterals		l1	l	l¢	l2	

Table 1b: Neutralization of apicals word-initially:

				Apical Coronals			
		Bilabial	Laminal Dental	Apical Alveolar	Apical Post-alveolar	Laminal Palato-alveolar	Dorsal Velar
Row 1:	Stops aC´	map´ *many (n)*	at1 *I (pr, tr.)*	la2t´ *today (n)*	kwat¢ *egg (n)*	kwat2 *water (n)*	mak´ *elbow (n)*
Row 2:	Stops #C´	p´t1 *pouch (n)*	t1m´ *grind (vt)*	t´p´ *back (n)*		t2n´ *friend (n)*	k´p´ *firestick (n)*
Row 3:	Nasals aC´	mam´ *sore (n)*	lan1 *there-mid (n)*	man´ *money (n)*	an¢ *ground (n)*	mpan2 *marriage (n)*	paN´ *blind (n)*
Row 4:	Nasals #C´	m´n¢ *veg. food (n)*	n1m´ *fall (rain) (vi)*	n´m´ *sit (vi)*		n2nt´ *one (n)*	N´m´ *fly (n)*
Row 5:	Laterals aC´		al1 *nose (n)*	pal´ *wrong (n)*	wal¢ *house (n)*	wal2 *leafy branches (n)*	
Row 6:	Laterals #C´		l1m´ *go (v)*	l´m´ *liver (n)*		l2m´ *to sing (vt)*	

B.) The second goal of the study was to examine any differences in native listeners' ability to identify apical postalveolars under two conditions: the case in which the preceding vowel was present, and the case in which it was absent. Investigators [1], [3] and [4] *(inter alios)* have proposed that a preceding vowel's formant transitions provide an important acoustic cue signaling postalveolar place. [4] and [1] make the stronger claim that the reason the two apicals do not contrast in initial position in many Australian and Indian languages is that there are no preceding vowel transitions to cue the difference between them. "Positional neutralization affects contrasts that are, to begin with, harder to perceive or execute, in positions that further add to an initial difficulty."[4] Butcher's electropalatographic articulatory studies of Australian languages [2] show results in concert with the idea of asymmetrical vowel formant transition cues: apical postalveolar stops often shift forward in place of articulation between articulatory closure and release. At release, such stops are more anterior than they are at closure, and have formant transitions more like alveolars. In light of this, we hypothesized that B1) Listeners would have greater difficulty perceiving place of articulation of apical postalveolars when preceding vowel information was removed.

2. METHOD

Twelve forced-choice perception tests were presented to nine native listeners. Tests were of two types; the first involved VCV stimuli—listeners heard randomized [áC´] nonsense disyllables digitized from the speech of two native speakers of W. Arrernte. For each manner and place of articulation (including the "peripherals"–labials and velars), and for each speaker, two [áC´] utterances were sampled, and each stimulus was presented for identification six times. The second type of test involved CV stimuli; listeners heard [C´] nonsense monosyllables excised from the VCV stimuli. Tokens were digitized (22 kHz, 8 bits) with Signalyze 3.0, and presented via Hypercard 2.0 stacks in which the experimenter also recorded responses. Each listener performed tests by himself, hearing stimuli via high quality headphones connected to a portable computer. The experimenter did not hear the stimuli. In both VCV and CV tests, manners of articulation were administered separately; i.e. listeners knew beforehand that the sound in question was one of the six stops, or one of the six nasals, or one of the four laterals. Moreover, for each test the speaker was held constant. Thus, in each case the listener's task was restricted to identification of the place of articulation of the stimulus.

Two training/screening tests were given to prospective subjects, to rule out subnormal hearing or non-comprehension of the task involved in the tests.

For all tests, the range of possible responses was limited to intervocalic segments. For each stimulus the subject chose a word in row 1, 3 or 5 of Table 1.b to represent the medial consonant he heard. There was no possibility of choosing a neutralized consonant. Listeners were pre-trained to listen for the medial consonant of a word, and thus for a contrast between apicals.

3. RESULTS AND DISCUSSION

2a.

	p	t1	t	t¢	t2	k
p-R	**85**	1	1	0	0	0
t1-R	12	**96**	10	1	1	3
t-R	3	1	**70**	24	0	1
t¢-R	0	1	19	**74**	0	2
t2-R	0	1	0	0	**99**	1
k-R	0	1	0	0	0	**94**

2b.

	m	n1	n	n¢	n2	N
m-R	**94**	0	0	0	1	0
n1-R	1	**75**	8	0	5	3
n-R	4	9	**62**	3	5	1
n¢-R	1	13	28	**96**	0	0
n2-R	1	3	1	1	**88**	2
N-R	0	0	1	0	2	**94**

2c.

	l1	l	l¢	l2
l1-R	**91**	8	2	3
l-R	6	**62**	12	2
l¢-R	2	29	**84**	1
l2-R	1	1	2	**95**

3.1 VCV Results

Despite good performance on screening tests, one listener had to be excluded from result summaries due to consistently poorer performance in correct responses, as well as zero percent correct responses in two nasal categories. These results led to doubt about her ability to perform the task. Results discussed below summarize eight listeners' responses.

Tables 2a, b and c show overall results for the VCV condition, for stops, nasals and laterals respectively. Actual place of articulation of stimuli is shown at the top row of each table; percent distribution of responses is shown in each column underneath. Boxes enclosed in double lines show correct responses. Shaded boxes show substantial misperception of tokens as another category.

Main results to be observed in responses to VCV tests follow. First, looking across places of articulation, stops do not show a higher overall percentage of correct identification than nasals or laterals. This refutes hypothesis A1. Next, looking across manner of articulation, several results emerge. First, peripherals are identified correctly a high proportion of the time. For all peripherals except \p\ correct identification was over 90%.[1] Results for peripherals thus provide us with a

[1]The 85% success rate for \p\ is attributable to one listener, who had a very uncharacteristic correct identification rate of only 21% for \p\. This listener's

control situation showing that listeners did not have trouble with the test procedures *per se.* Second, turning to coronals, laminal palatoalveolars are very robust in correct identification, across manners. (Stops 99%, laterals 95%, nasals 88%.) Third, apical alveolars fare worst in correct identification, for stops (70%), nasals (62%) and laterals (62%) alike. Looking at *misperceptions* of alveolars, apical postalveolars predominate, followed by laminal dentals; this effect holds across manners of articulation. Fourth, taking the laminal dentals and apical postalveolars under consideration, there is a place–manner interaction for these segments. For laminal dentals, stops seem to have the most robust place cues; they are identified correctly 96% of the time, followed by laterals (91%) and nasals (only 75%). For the postalveolars the reverse is true: nasals are very robust (96% correct identification), followed by laterals (84%) and stops (74%). To summarize the VCV results, while peripherals and laminal palatoalveolars are perceptually very robust, both apicals are substantially less discriminable, for stops and laterals. For nasals, the laminal dental and apical alveolar are less discriminable. Thus in answer to hypothesis A2 there is a basis on which to say that apical alveolars, at least, are inherently more difficult to perceive than other places of articulation, for native listeners.

Acoustic analysis of coronal stimuli provide instructive clues as to the cues listeners may have been using to correctly identify tokens. Analysis of variance (ANOVA) showed that place of articulation has a significant main effect on formant transition values, formants during nasal/lateral murmur, duration of voiceless closure, VOT and "affrication quotient" (explained below.) Any results discussed below are significant in Fisher's PLSD post hoc comparisons, at at least a p=.05 level. Recall, however, that each category mean reflects only four tokens.

Across manners, laminal palatoalveolars have significantly lower F1, and higher F2 and F3 formant transitions on both V1 and V2 sides of the segment than do other coronals. Palatoalveolar stops have a significantly longer VOT than other stops, and that VOT is affricated for all of its duration. Palatoalveolar sonorants have a higher F2 during the murmur itself than other places of articulation.

Laminal dental stops and postalveolar nasals were the other robust segments. The \t1 has the longest voiceless closure duration of any of the stops. This is probably an important cue, since these stops lose some 13% discriminability in the CV condition when this is absent. On the V2 side, the laminal dental stop has the lowest ratio of high energy frication to VOT. That is, while \t2 is fricated for the entire length of its VOT (affrication quotient=1), \t1 is only fricated for slightly more than half its VOT time (aff.quot.=.6) Moreover, three of four tokens of \t1 had double bursts, which was not true of any of the other coronal stops. On the other hand, laminal dental sonorants could not be completely separated statistically from other place categories in any ANOVA, which parallels listeners' less robust perception of these segments.

The \n¢ was characterized by significantly lower F3 transitions than for other nasals, on both sides of the segment. For \n¢, the abrupt discontinuity between vowel and nasal characteristic of both apicals, and more importantly, the high-amplitude, low frequency F3 transitions unique to the postalveolar probably account for \n¢'s perceptual robustness. Interestingly, for \t¢ and \ l¢, though F3 was lower on the V1 side, V2 transitions were not significantly differentiable from those of alveolars or dentals. In the case of \n¢, the added difference in F3 on the V2 side may account for its greater perceptual robustness.

An interesting segment–speaker interaction gives us clues to the important cues for laminal dental and apical postalveolar stops. Most listeners who misperceived \t\ as \t1 did so when hearing the speaker whose tokens of \t\ include a short voiceless closure. On the other hand, listeners who heard \t\ as \t¢ were listening to the speaker whose tokens of \t\ were completely voiced throughout the closure.

3.2 CV Results

3a.

	p	t1	t	t¢	t2	k
p-R	**83**	3	1	5	1	1
t1-R	11	**83**	27	47	3	2
t-R	1	4	**35**	18	1	1
t¢-R	3	4	28	**19**	1	3
t2-R	1	1	1	2	**94**	2
k-R	1	6	8	9	1	**92**

3b.

	m	n1	n	n¢	n2	N
m-R	**93**	1	1	2	2	1
n1-R	3	**70**	19	41	3	2
n-R	1	8	**45**	21	2	2
n¢-R	1	14	30	**28**	1	3
n2-R	1	3	2	5	**87**	3
N-R	2	4	5	4	6	**90**

3c.

	l1	l	l¢	l2
l1-R	**55**	29	27	3
l-R	17	**32**	24	2
l¢-R	20	37	**45**	3
l2-R	7	2	4	**92**

Tables 3a, b and c show results for the CV condition, for stops, nasals and laterals respectively. Across manners of articulation, rates of successful identification for peripherals and laminal palatoalveolars remain unchanged. These segments are as robust in the CV condition as in the VCV condition. This tells us that

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results were not excluded, since our focus here is on coronals rather than peripherals.

many of the important acoustic cues used by listeners are on the V2 side of these segments. Laminal dentals lose some discriminability in the CV situation in stops and nasals, and more in laterals. This points to the importance of V1 side cues (such as the long voiceless closure in intervocalic \t\ and the long murmur for nasals and laterals, as well as the duration of V1 itself, as discussed below.) However, the most significant finding of the study is that in the CV condition, all apical alveolars and postalveolars drop below 50% correct identification rate. From this we can conclude that, unlike peripherals and palatoalveolars, the critical cues to these places of articulation are on the V1 side; without these the apicals cannot be identified correctly. Furthermore, there is much more intrusion of the incorrect percept of laminal dental for both apicals in the CV condition; not only for alveolars, where the effect was significant but small before, but for postalveolars too. In fact, for postalveolar stops and nasals, laminal dentals account for more responses than the postalveolar category itself. Once again, these results are in line with Butcher's observation that postalveolar articulations may be further forward at release than at closure [2]; and they may perhaps be as far forward as dentals.

The important V1 side cues that are lost in the CV condition include duration and V1 formant transition information. Across manners, the preceding vowel is significantly longer before apicals than before laminals. Duration of voiceless closure for stops, and duration of murmur for nasals and laterals, is also important. Voiceless closures are shortest (often nonexistent) for \t¢\, short for \t\, longer for \t2\, and longest for \t1\. Murmurs are significantly shorter in duration for apicals than they are for laminals. While voiceless closure disappears entirely in the CV condition, explaining the drop in correct percent identification of \t1\, murmur durations remain, for the sonorants. However, murmur duration cues may lose some salience when the preceding vowel is absent because the listener cannot normalize the duration of the murmur against a preceding vowel.

However, the most obvious difference between VCV and CV cases, for all manners of articulation, is the lack of V1 formant transition information in the CV condition. Apical postalveolars have a very characteristic pattern of formant proximity in F2, F3 and F4 at onset that provides a major cue to place. This characteristic is absent on the V2 side, except in tokens of \n¢\. (Even so, poor identification of \n¢\ in the CV condition shows that it is the V1 side transitions that listeners use in making a postalveolar place judgment.) On the V2 side, laminal dentals, apical alveolars and apical postalveolars are all much more similar in their formant transitions.

4. CONCLUSION

Hypothesis A1 was not borne out. Stops are not more perceptually robust than nasals or laterals for native listeners. Hypothesis A2 was borne out, for apical alveolars, and to a lesser extent for apical postalveolars; apicals are less perceptually robust than other coronals, even for native listeners. When misheard in the VCV condition, apicals show some tendency to be heard as the other apical, though there is also some misperception as laminal dental for apical alveolars. The low functional load of the apical contrast may well affect its perceptual robustness, or it may be that functional load is low because of the inherent difficulty in discriminating these two places. This study cannot address the directionality of this point, but note that apical alveolars seem to be inherently weak in their acoustic cues. We can statistically separate acoustic cues for the other places (laminal palatoalveolars: long, affricated VOT, very high F2 and F3 transitions; apical postalveolars: V1 formant transitions, lack of VOT, very low energy burst; laminal dentals: long voiceless closure, double burst, low affrication quotient.) Apical alveolars, however, can be voiced or voiceless, have a high or low energy burst, and do not have formant transitions distinct from laminal dentals (or apical postalveolars, on the V2 side.) Apical alveolars may be recovered from the signal by default.

Hypothesis B1 was borne out. In the CV condition, correct identification of both apical alveolars and apical postalveolars drops dramatically, while laminal dentals lose some discriminability and other places remain robustly discriminable. This confirms the importance of a preceding vowel's formant transitions in distinguishing postalveolars from alveolars. Moreover, for stops and nasals, apical postalveolars are misheard as laminal dentals, more often than any other coronal category, which could imply a tongue position at release that is even further forward than that of apical alveolars.

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REFERENCES

[1] V. Anderson, "Articulation, acoustics and perception of Western Arrernte coronals", UCLA doctoral dissertation, in progress.

[2] A. Butcher, "The Phonetics of Australian Languages", in progress.

[3] S. Spajic, P. Ladefoged and P. Bhaskararao, "The rhotics of Toda", *UCLA Working Papers in Phonetics,* Vol. 87, pp. 35-66, 1994.

[4] D. Steriade, "Positional neutralization", in progress.