CONSONANTAL COARTICULATION RESISTANCE IN VOWEL-CONSONANT-VOWEL SEQUENCES

Simone Graetzer

School of Languages and Linguistics, University of Melbourne, Australia
n.graetzer@pgrad.unimelb.edu.au

ABSTRACT

Formant two distribution for Arrernte and Burarra, two Australian languages, at V^1-offset and V^2-onset in V^1CV^2 sequences, reveals that stop consonants differ in resistance to coarticulation by adjacent vowels. While the two languages display slightly dissimilar patterns of resistance, they share a strong tendency towards greater variation in V^1-offset, suggesting that the effects of coarticulation resistance are strongest immediately after intervocalic consonants in these languages.

Keywords: consonant, coarticulation, resistance.

1. INTRODUCTION

This paper reports on a quantitative, acoustical study of consonantal coarticulation resistance in vowel-consonant-vowel sequences in two Australian aboriginal languages: Arrernte and Burarra.

Coarticulation resistance may be defined as the extent to which some segment resists the articulatory influences of a neighbouring segment or segments. It is found in three main contexts: when resistance prevents the confounding of paradigmatic contrasts by heightening phonetic clarity, when articulatory strengthening of segments is induced by prosody or pragmatics [7], and when segments are inherently strong articulatorily [12]. Coarticulation resistance for a given segment may vary according to whether or not, and the extent to which, a given segment shares articulators with one or more adjacent segments [12].

The main research goal of the current study was to determine whether stop consonants differ in resistance to the potential coarticulatory influences of neighbouring vowels in the speech of Arrernte and Burarra speakers. It is important to examine coarticulation resistance in these languages for two main reasons: one, because coarticulation resistance in one or more Australian languages has not previously been the subject of any instrumental phonetic study, and two, because the consonant inventories of Australian languages have many places of articulation (in turn, because the need to preserve distinctions between multiple places of articulations is likely to relate to coarticulation resistance, see e.g., [2], [7]). Based on earlier work (e.g., [8], [14]), consistent differences in coarticulation resistance are expected, such that labial consonants will be weakly resistant, and palatal consonants strongly resistant.

The metric employed in this paper is variation in formant two (F2) distribution for V^1-offsets and V^2-onsets in V^1CV^2 (vowel-consonant-vowel) sequences, where C is limited to /p, t, t̪, c, k/. This metric is intended, firstly, to indicate the extent to which the intervocalic consonant constrains the range of possible F2 frequencies at V^1-offsets and V^2-onsets, such that, given that consonants with low coarticulation resistance are known to exert weaker influence on adjacent vowels, larger ranges would indicate the lower coarticulation resistance of the intervocalic consonant (see [12], [13]). This metric would thereby allow a comparison of consonants in terms of resistance to coarticulation by adjacent vowels, and a comparison of the range of F2 frequencies before and after the consonant, thus providing an indication of whether the effects of consonantal coarticulation resistance are greater before or after the consonant. A similar metric has been used, for example, in analyses of consonant-vowel, vowel-consonant, and vowel-to-vowel coarticulation, and also coproduction effects (see e.g., [11], [14]).

2. METHODS AND MATERIALS

The two languages investigated in this study are Arrernte and Burarra. Arrernte is an Arandic, Pama-Nyungan language spoken in Central Australia, which has twenty-seven phonemic consonants and four phonemic vowels, comprising /i, ə, a, u/ [1]. The phonemic consonant inventory comprises oral voiceless plosives, voiced nasal plosives, and pre-stopped nasals in all six places of articulation (bilabial, dental, alveolar, postalveolar, palatal, and velar), voiced lateral approximants in dental, alveolar, postalveolar, and palatal places of articulation, an alveolar trill, a velar fricative, a postalveolar tap, and bilabial and palatal approximants. Burarra is a non-Pama-Nyungan language spoken in Arnhem Land, which has twenty-one phonemic consonants and five vowels, comprising /ɪ, ɛ, ɐ, ɒ, u/ [9]. The consonant inventory comprises oral fortis and lenis plosives in all five places of articulation (bilabial, alveolar, postalveolar, palatal, and velar), voiced nasal plosives in bilabial, postalveolar, palatal, and velar places of articulation, an alveolar trill, voiced non-lateral approximants in both postalveolar and palatal places of articulation, and lateral approximants in both alveolar and postalveolar places of articulation. The consonants chosen for this study can be categorised as fortis consonants, where "fortis" indicates greater intra-oral peak pressure and stricture duration than in "lenis" counterparts. One fortis/lenis pair is, for example, /b/ and /p/.

The corpus consists of 971 words from Arrernte (speaker 1, 276; speaker 2, 322) and Burarra (speaker 3, 287; speaker 4, 86) elicited from four adult female speakers. The corpus was collected and digitised by Professor Andrew Butcher. Tokens were extracted from the corpus using Praat version 4.3.12. The extracted tokens were labelled using the EMU Speech Database System Version 2.0.1 (see e.g., [6]). In EMU, within-word V^1CV^2 sequences were picked out for analysis when C was /p, t, ʈ, c/ or /k/. Intervocalic consonants were chosen on account of neutralisation in these languages (see [4]). The EMU system formant-tracking algorithm (see [6]) was applied to determine the midpoint of the F2 resonant frequencies recorded at a given time value. (The midpoint is conventionally accepted as providing sufficient information about formant frequency.) The relevant time boundaries occurred at vowel offset and vowel onset; vowel offset boundaries, when vowels precede the consonants under observation, were placed at the offset of regular periodicity in the waveform, and vowel onset boundaries, when vowels follow the consonants, were placed at the onset of regular periodicity. Algorithm induced formant-tracking errors were hand-corrected when necessary. Formant (F2) values were then extracted at measurement points using EMU(R Version 2.1.1) and statistical analyses were performed. Variation between (same-gender) speakers of the same language appeared insignificant on a visual inspection of the data. The resistance of a consonant to coarticulation is here averaged across vowel environments. The uneven distribution of vowel types cannot be discounted as a confounding factor, on account of the small size of the current corpus not permitting empirical verification of invariant resistance across vowel contexts (c.f. e.g., [5]). However, vowel type distribution was similar across all factors (speaker, language, etc.) when subjected to a frequency analysis.

In this paper, markedly different medians in F2 distribution for V^1-offsets and V^2-onsets, e.g., the offset median falling outside of the range for the onset median, are taken to indicate markedly different distribution, and by extension, weak coarticulation resistance.

3. RESULTS

Figures 1 to 3 plot F2 V^1-offset values and F2 V^2-onset values for /p, t, ʈ, c, k/ across vowel environments. Within each plot, the offset range appears to the left, and the onset range to the right. The boxplots show the median (indicated by a vertical line), first, and third quantiles. Merely that variation that is between the first and third quantiles, i.e., between the lower and upper boundaries of the box, is discussed here.

Figure 1 plots values for /p/. For Arrernte and Burarra speakers, shown in left (hereafter L) and right (hereafter R) plots, respectively, V^1-offset and V^2-onset ranges and their medians differ markedly, providing strong evidence for weak consonantal coarticulation resistance. Smaller ranges for both languages at V^2-onset suggest that the acoustic effects of coarticulation resistance are greater at V^2-onset than at V^1-offset for /p/. Consider boxplots for /t/ (Fig. 2). Observe that V^1-offset and V^2-onset ranges are greater for /t/ in Arrernte (L) than in Burarra (R). Furthermore, medians are markedly different for /t/ in Burarra (but not Arrernte), indicating weak coarticulation resistance in Burarra. Turning to /ʈ/ (Fig. 2), compare the very large range of offset values for Arrernte (L), to the very limited range of onset values for the same language (L). The same contrast between offset and onset ranges is seen for Burarra (R), but on a smaller scale. These results suggest that /ʈ/ is somewhat coarticulation resistant. For /t/ and /ʈ/ in both languages, V^2-onset ranges are smaller than V^1-offset ranges, indicating that the coarticulation resistance effects between the consonant and adjacent vowel(s) are larger at V^2-onset than elsewhere. With respect to /c/ (Fig. 3), observe that ranges are relatively small, especially for Burarra (R), and ranges are more similar across V^1-offset and V^2-onset than for

Figure 1: Boxplots for V^1-offset and V^2-onset for /V^1pV^2/ for both languages (Arrernte, L, Burarra, R)

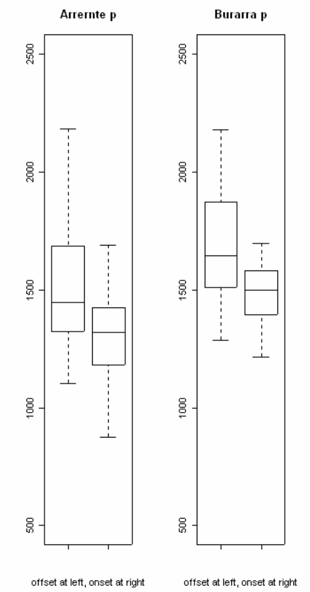


Figure 2: Boxplots for V^1-offset and V^2-onset for /V^1tV^2/ and /V^1ʈV^2/ for both languages (for each C, Arrernte, L, Burarra, R)

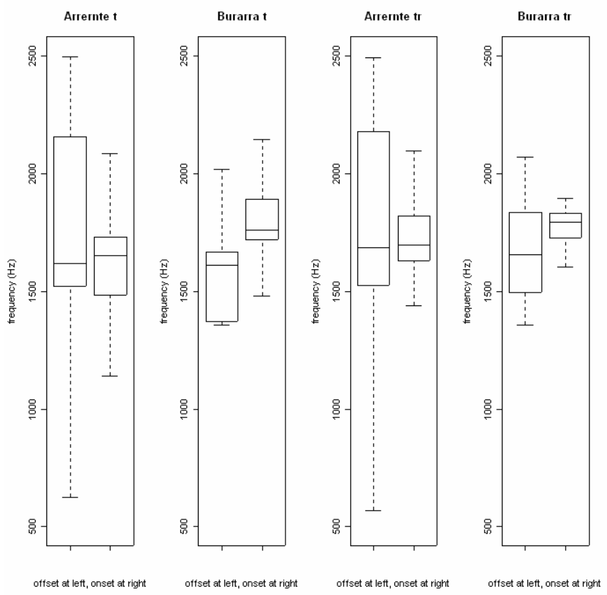
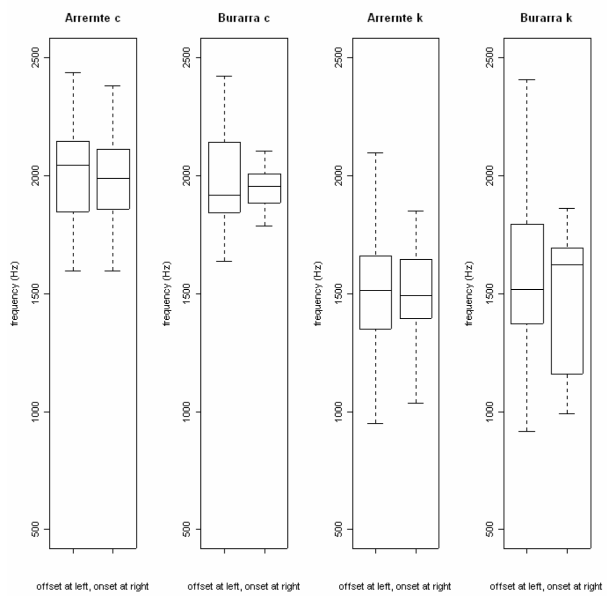


Figure 3: Boxplots for V^1-offset and V^2-onset for /V^1cV^2/ and /V^1kV^2/ for both languages (for each C, Arrernte, L, Burarra, R)



previous consonants, however, the V^1-offset range is again larger for both languages. For /k/ in Burarra (far R), ranges are of moderate size, and the V^2-onset range (merely between the lower and upper boundaries of the box) is larger. Finally, across all results, only for /k/ in Burarra is the V^1-offset range not greater than the V^2-onset range.

4. DISCUSSION

As stated, greater F2 variability in the vowel at V^1-offset or V^2-onset in V^1CV^2 sequences is taken to indicate lower consonantal coarticulation resistance to adjacent vowel effects.

For Arrernte, the greatest difference between V^1-offset and V^2-onset ranges (as indicated by relative placement of medians) occurs for /p/, and indicates weak resistance, as found in previous studies (e.g., [14]). Moderate resistance is present for /t/ for Arrernte speakers. However, for Burarra, both /p/ and /t/ display a marked difference between offset and onset ranges (as indicated by relative placement of medians), suggesting weak coarticulation resistance for both consonants. A probable articulatory explanation for results for /p/ is that labial consonants do not involve lingual activity that would conflict with a gesture or gestures for the transconsonantal vowels. Results for /ʈ/ in both languages suggest that it is quite coarticulation resistant - possibly because of an inability to raise and curl back the tongue front to execute the consonant, and simultaneously adjust the height of the tongue dorsum to coarticulate with adjacent vowels. The majority of the /p/, /t/, and /ʈ/ resistance effects is clearly realised immediately after the consonant, rather than before, given that ranges are very much smaller for V^2-onset than V^1-offset. For /c/, for both language groups, ranges are smallest, and V^1-offset and V^2-onset ranges are highly similar, indicating very high coarticulation resistance for this consonant. Even so, V^2-onset ranges are slightly smaller, suggesting that this range is more tightly controlled. For /k/, in Arrernte but not Burarra, V^1-offset and V^2-onset ranges are very similar, and ranges are smaller for Arrernte than for Burarra, i.e., /k/ appears to be highly coarticulation resistant in Arrernte, and less resistant in Burarra. The finding of high coarticulation resistance for /k/ in Arrernte does not accord with results for related languages, Yanyuwa and Yindjibarndi: it might indicate that there are no distinct palato- and dorso-velar allophones of /k/ in Arrernte (see, e.g., [3], [12], [14]). The findings for palatal and velar consonants are readily explained - the production of palatal and velar consonants requires use of the tongue body in conflict with the production of vowels, thereby restricting coarticulation by adjacent vowels [10]. /c/ is both a close and front constriction, which places significant constraints on the tongue, whereas /k/ is produced with the tongue dorsum, which is relatively slow-moving.

It should be acknowledged that the results cannot sensibly be interpreted in respect of vowel-to-vowel coarticulation, because it is not possible to separate out contributing factors at this stage.

In summary, results for this experiment show clear and consistent effects of coarticulation resistance differences between stop consonants. In addition, a very strong tendency for greater variation in V^1-offset than V^2-onset indicates that the effects of coarticulation resistance on transconsonantal vowels are greatest immediately after the consonant in these languages.

5. CONCLUSION

This paper contributes to an understanding of coarticulation by examining consonantal coarticulation resistance in two Australian languages. As predicted, the results provide evidence for a relationship between consonant identity and variability in V^1-offsets and V^2-onsets in V^1CV^2 sequences, and by extension between consonant identity and coarticulation resistance.

On the basis of these results, it would appear profitable to extend the current study to better investigate the relationships between coarticulation resistance, phonemic inventory, and consonant-vowel/vowel-consonant and vowel-to-vowel coarticulation. In future research, the issues of collapsing results across speakers, and averaging consonantal coarticulation resistance across vowel environments, will be addressed.

6. REFERENCES

[1] Breen, G., Dobson, V. 2005. Central Arrernte. *Journal of the International Phonetic Association* 35(2), 249-254.

[2] Butcher, A.R. 2006. Australian Aboriginal languages: consonant-salient phonologies and the 'place-of-articulation imperative'. In: Harrington, J.M., and Tabain, M. (eds.), *Speech Production: Models, Phonetic Processes and Techniques* (chap. 12). New York: Psychology Press.

[3] Butcher, A., Tabain, M. 2004. On the back of the tongue: dorsal sounds in Australian languages. *Phonetica* 61, 22-52.

[4] Capell, A. 1967. Sound systems in Australia. *Phonetica* 16, 85-110.

[5] Carre, R. 1998. Linear correlates in the speech signal: consequences of the specific use of an acoustic tube? *The Behavioral and Brain Sciences* 21, 261-262.

[6] Cassidy, S., Harrington, J. 2004. EMU README; The EMU Speech Database System. http://emu.sourceforge.net/ visited 1-Jun-05.

[7] Cho, T. 2004. Prosodically conditioned strengthening and vowel-to-vowel coarticulation in English. *Journal of Phonetics* 32, 141-176.

[8] Fowler, C.A., Brancazio, L. 2000. Coarticulation Resistance of American English Consonants and its Effects on Transconsonantal Vowel-to-Vowel Coarticulation. *Language and Speech* 43(1), 1-41.

[9] Glasgow, K. 1981. Burarra phonemes. In: Waters, B. (ed.), *Australian phonologies: Collected papers*, 63-89, Work papers of the Summer Institute of Linguistics, Australian Aborigines Branch (SIL-AAB), Series A, Vol. 5. Darwin: Summer Institute of Linguistics.

[10] Magen, H.S. 1997. The extent of vowel-to-vowel coarticulation in English. *Journal of Phonetics* 25, 187-205.

[11] Ohman, S.E.G. 1966. Coarticulation in VCV utterances: Spectrographic measurements. *Journal of the Acoustical Society of America* 39, 151-68.

[12] Recasens, D. 1985. Coarticulatory patterns and degrees of coarticulation resistance in Catalan CV sequences. *Language and Speech* 28(2), 97-114.

[13] Recasens, D. 1987. An acoustic analysis of V-to-C and V-to-V coarticulatory effects in Catalan and Spanish VCV sequences. *Journal of Phonetics* 15, 299-312.

[14] Tabain, M., Butcher, A. 1999. Stop consonants in Yanyuwa and Yindjibarndi: locus equation data. *Journal of Phonetics* 27, 333-357.