NASAL CONSONANTS IN YANYUWA AND YINDJIBARNDI: AN ACOUSTIC STUDY

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ABSTRACT - This study looks at nasal consonants in two Australian languages, Yanyuwa and Yindjibarndi. Locus equations are used to find evidence for acoustic loci for these consonants, and also to investigate the degree of coarticulation with the following vowel involved in their production. Results strongly suggest that despite having a large nasal consonant inventory, and a small vowel inventory, Yanyuwa and Yindjibarndi show a great deal of coarticulation in their nasal consonants according to vowel context.

INTRODUCTION

Australian languages are well-known for their large inventory of consonants, including up to seven place-of-articulation contrasts for stops and nasals. Yindjibarndi, spoken in northern Western Australia (mostly around Roebourne) has six places-of-articulation for both the oral and nasal stops; Yanyuwa, spoken in the south-west corner of the Gulf of Carpentaria, has seven places-of-articulation. Both have (from front to back of the vocal tract) a bi-labial /m/, a lamino-dental /nh/, an apico-alveolar /n/, an apico-postalveolar (often retroflex) /rn/, a lamino-palatal /ny/ and a velar /ng/. Yanyuwa also has a palato-velar /yng/, produced using the tongue dorsum -- it is assumed to be articulated somewhere between the palatal and velar regions.

Australian languages tend to have small vowel inventories -- indeed, both Yanyuwa and Yindjibarndi have a three-vowel system, consisting of /a/, /i/ and /u/. Writers on Australian languages (e.g. Dixon 1980) often comment on the large amount of allophonic variation in the vowels of these languages. It is often assumed that, as a consequence of the larger consonant inventory, consonants are not free to show the same amount of allophonic variation that vowels do (Keating 1990). The present study aims to explore this assumption with reference to nasal consonants. Locus equations are used not just to give an acoustic locus for each place-of-articulation, but to look at the amount of anticipatory coarticulation in a CV context (where C is nasal). If anticipatory coarticulation, as represented by a slope value, is high, then it can be said that there is a good deal of allophonic variation for that consonant according to vowel context.

Note that in both languages, the lamino-dental /nh/ does not occur before /i/, and that in Yindjibarndi, the velar /ng/ does not occur before /i/ nor /rn/ before /u/. Further, the palatalized velar /yng/ of Yanyuwa occurs only before /u/ -- this palatalized velar is discussed in the results section.

METHOD

Three Yanyuwa and three Yindjibarndi speakers (two female and one male for each language) served as subjects for this study. The same speakers served as subjects for the palatographic study of these languages carried out by Butcher (1994). Word-lists compiled by Butcher formed the corpus for the present study. Nasal segments are presented in both word-initial and word-internal position, in both stressed and unstressed syllables. As Australian languages prefer a CV syllable structure, the current study focuses on CV syllables only.

Each speaker produced three tokens of each word. Tokens were rejected if speech could not be reliably isolated in the spectrographic analysis. The total number of tokens was 716 for Yanyuwa out of a possible 756, and 614 tokens for Yindjibarndi out of a possible 666.

Spectrograms of the tokens were made using a Kay DSP5500 broadband sonagraph at Melbourne University. An 8 kHz sampling rate was used, and the display included a wideband power spectrum and waveform. Hand measurements were made of the second formant at both the vowel onset and the vowel target in CV syllables.

Following Lindblom (1963), locus equations were generated using customised Splus routines in the mu+ system at Macquarie University (Harrington *et al.* 1993). F2-onset is plotted on the y-axis, and is a function of F2-target plotted on the x-axis. A line-of-best-fit is then calculated, giving a slope value and a y-intercept value. Assuming a straight line transition between F2 vowel onset and F2 vowel target, it can be shown that the point-of-intersection of this line-of-best-fit with the line y=x (i.e. formant onset = formant target) is the best estimate of the locus frequency (Sussman *et al.* 1991, Sussman *et al.* 1993). This estimated value therefore represents the acoustic locus for F2 for a given consonant place-of-articulation. The slope value tells us how much that locus varies according to the following vowel: a slope value of zero means that there is an invariant locus for the consonant, whereas a value of one means that there is maximum co-articulation with the following vowel (Krull 1989).

RESULTS AND DISCUSSION

Individual speaker results suggest a labial locus at around 800-900 Hz, as expected, with a high slope value (0.7) indicative of the high degree of coarticulation with the following vowel. The apicals tended to have varying loci, generally between 1200-1700 Hz; the retroflex locus was somewhat higher than that of the alveolar. Like the labial, the apicals tended to have slope values at about 0.7, suggesting that the tongue-tip articulation does indeed leave the tongue body free to anticipate the following vowel. The laminal articulations, by contrast, tended to have lower slope values, at around 0.3 - 0.4, thereby reflecting the fact that the tongue body is a lot more constrained by this articulation. This low slope value results in the generally higher locus values for these consonants: 1300-2000 Hz for the lamino-dental, and 2300-3000 Hz for the palatal. The velar, by contrast, showed by far the greatest degree of coarticulation. Slope values approaching 1.00 were typical, suggesting a very high level of co-articulation with the following vowel.

Data were then speaker-normalised following Lobanov (1971) and combined for each language. The locus equations generated after normalisation can be seen in Figure 1 (for Yanyuwa) and Figure 2 (for Yindjibarndi). Notably, the plot for the velar nasal in Yanyuwa shows a slope value of 1.00, but a negative reading for the locus value, suggesting that there really is no locus for the velar in this case (a negative value has no other meaning). Indeed, since a value of 1 represents maximum coarticulation with the following vowel, it is to be expected that there should be no "real" locus value. By contrast, the combined data for Yindjibarndi showed a slope value of 0.72 for the velar, and a locus value of 1081 Hz. This locus value is what one would expect for a "grave" consonant.

The labial locus plots for Yanyuwa and Yindjibarndi have slope values around 0.7 and a locus at 895 Hz and 797 Hz respectively. The apicals /n/ and /rn/ also have slope values around 0.7, with a locus at around 1660 Hz for Yanyuwa, and at 1200 for /n/ and 1446 Hz for /rn/ for Yindjibarndi. These high slope values indicate that there is a good deal of anticipatory coarticulation not just in the labials (which is to be expected given that there are no constraints on the tongue), but in the apicals as well.

Figure 1: F2 locus equations for the nasal phonemes of Yanyuwa (the palato-velar is not included, as explained in the text). F2 target is plotted on the x-axis, and F2 onset on the y-axis. Data for three speakers, normalised following Lobanov (1971). The solid line is the line-of-best-fit, and the dotted line is the line y=x.

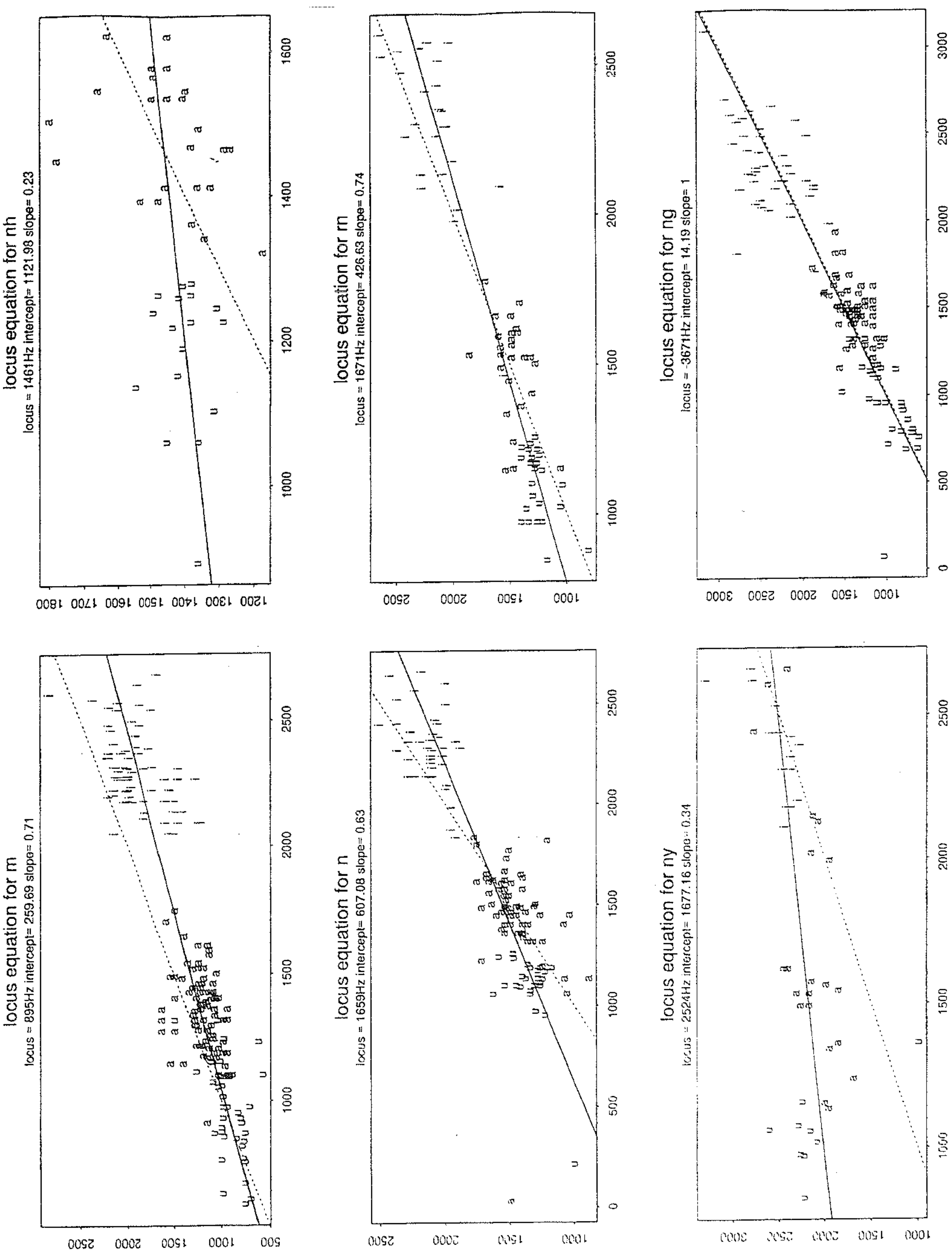
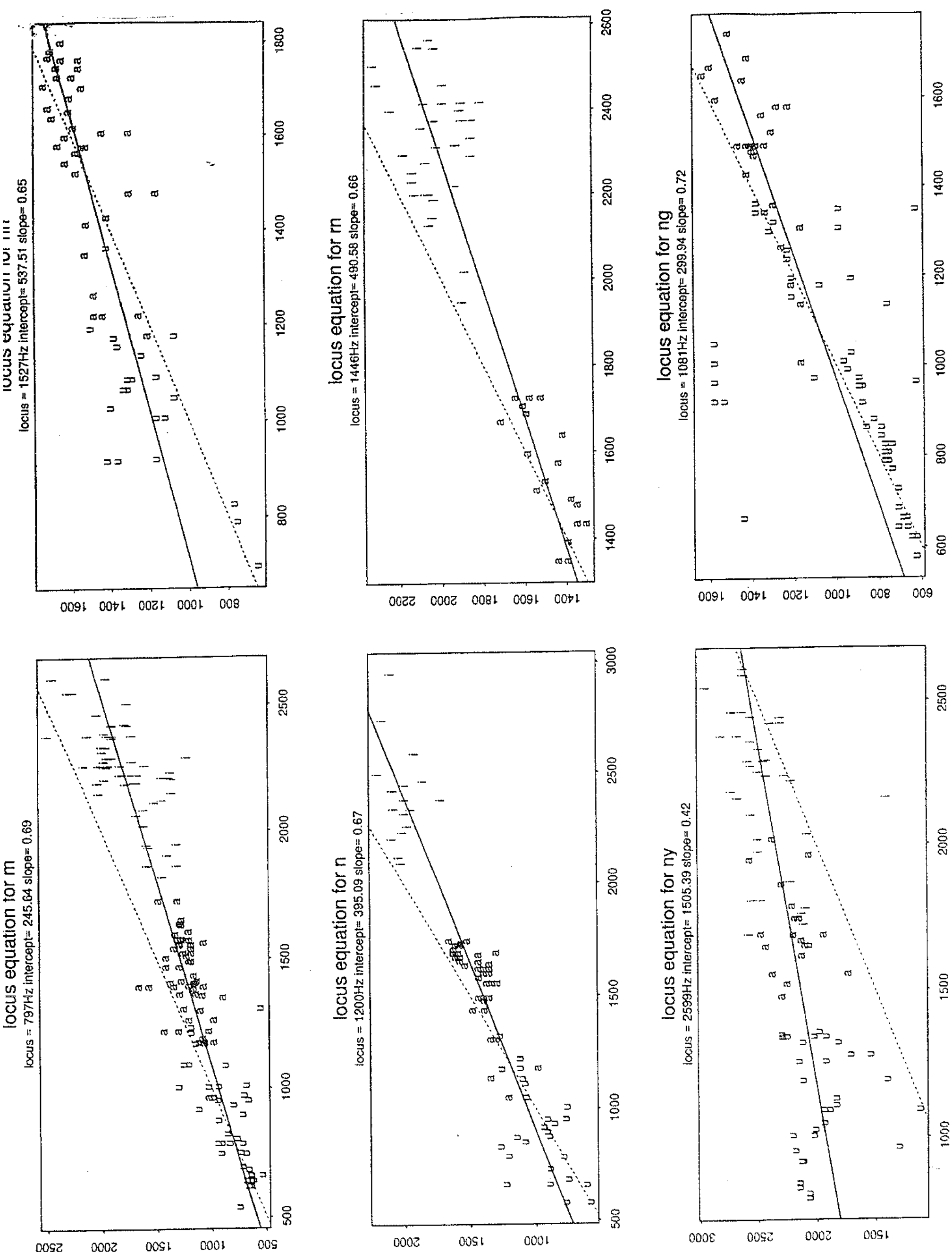


Figure 2: F2 locus equations for the nasal phonemes of Yindjibarndi. F2 target is plotted on the x-axis, and F2 onset on the y-axis. Data for three speakers, normalised following Lobanov (1971). The solid line is the line-of-best-fit, and the dotted line is the line y=x.



The laminals /nh/ and /ny/, by contrast, have much lower slope values. For Yanyuwa, the slope values are at around 0.3, with locus values of 1461 Hz for /nh/ and 2524 Hz for /ny/. For Yindjibarndi, /nh/ has a slope value of 0.65 and a locus value of 1527 Hz, while /ny/ has a slope value of 0.42 and an intercept value of 2599 Hz. The laminal articulation constrains the tongue-body, and prevents it from anticipating the following vowel, thereby resulting in the lowered slope values. The higher locus values, especially those of the palatal, reflect the extent of the F2 transition involved as a result of this tongue-body constraint.

Since the palato-velar of Yanyuwa occurs in only one vowel context (namely, before /u/), locus equations could not be calculated for this nasal. However, vowel onset and offset values strongly suggest that this "palato-velar," regardless of its phonological function, is realised as a sequence of a palatal semi-vowel and a velar nasal. Onset values for the following [u] tend around 1000 Hz, whereas offset values from the preceding vowel [a] tend around 2000-2500 Hz. Moreover, duration of the "vowel transition" from the [a] into the palato-velar resembles a semi-vowel (90-100 ms) far more than it does a consonant-vowel transition (in this study, vowel transitions tended around 30-40 ms for all consonant contexts except /ny/, which tended around 60 ms). As can be seen from the locus plots in Figure 1, onset values at around 1000 Hz before /u/ are to be expected of velars rather than palatals, whereas onset values of 2000-2500 Hz before /a/ are really only found for palatals.

Whether this palatal semi-vowel/velar nasal sequence is only a comparatively recent realisation of the palato-velar phoneme cannot be determined. Kirton and Charlie (1979) base part of their phonemic analysis of Yanyuwa on Peter Ladefoged's field work on this language. In particular, Ladefoged commented that the velar nasal appears to be articulated further back in the oral cavity in order to make room for the palato-velar. Whilst the present study does not present articulatory data, the acoustic data suggest that this is not the case. Not only do the above-mentioned onset/offset values and transition durations suggest a semi-vowel/nasal sequence, but the slope values of the velar nasal phoneme itself suggest that it is articulated further forward in the oral cavity when vowel context demands. Indeed, the velar slope values for Yanyuwa are very similar to those for Yindjibarndi, which does not have the palato-velar phoneme.

CONCLUSION

These results suggest that despite having a very large nasal consonant inventory, and a very small (three-) vowel inventory, Yanyuwa and Yindjibarndi show a great deal of coarticulation in their nasal consonants according to vowel context. This is contrary to the popularly-held view that the greater number of places-of-articulation in Australian languages (as compared to, say, English) results in little or no allophonic variation for consonants. The nasal data presented here indicate that the velar and the labial show just as much coarticulation with the following vowel in Yanyuwa and Yindjibarndi as they do in English. The apical articulations have similarly high coarticulation scores (as represented by the slope value), but the laminal articulations do not. Their slope values tend to be lower, and their locus values higher. Results for the palato-velar nasal phoneme of Yanyuwa suggest that it consists of a palatal semi-vowel followed by a velar nasal.

Whilst this study has looked at coarticulation in a consonant-vowel context, it has not investigated the *amount* of allophonic variation within each consonant phoneme, nor at the amount of overlap (if any) between these consonants. In particular, is a phoneme which is part of a six or seven-place system allowed more allophonic variation, or a wider range of F2 onset values, than a phoneme in a three-place system? Further work will look at this question of "phoneme space" in relation to the nasals described in this paper.

Further work also needs to be done to ascertain whether or not the observations made here regarding nasal consonants in Yanyuwa and Yindjibarndi can be extended to include stops, and other Australian languages. Locus equations are a powerful tool for the study of coarticulation given only acoustic data, and as such can be used to examine other possible allophonic variation of consonants in Australian languages.

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