Aspects of nasal realization and the place of articulation imperative in Bininj Gun-wok

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Abstract

Vowel transition duration is often claimed to be one of the important cues to place of articulation in nasals. Nasal murmurs also differ in duration depending on place of articulation. The duration of nasal murmurs and vowel transitions in different VNC and VN sequences were measured in the Kunwinjku variety of Bininj Gun-wok. Bilabial and velar nasals tend to be longer than alveolars and retroflexes in nasal–C clusters. Moreover, nasals in clusters are somewhat longer than singleton nasals. Significantly longer vowel transitions are found in alveopalatal and retroflex clusters than in bilabial or alveolar clusters. These results are interpreted in terms of general articulatory constraints as well as a specific constraint that operates in place-rich Australian languages, namely, the need to preserve place of articulation contrasts in VNC contexts.

Index Terms: speech production, acoustics, Australian languages

1. Introduction

It is well known that one of the distinguishing features of Australian indigenous languages is the need to maintain a large number of place of articulation (POA) contrasts in stops and sonorants including nasals and laterals. This is often found as the "place of articulation imperative" [1]. A range of acoustic features cue different place of articulation contrasts in languages, including formant transitions, gross spectral shape and properties of burst spectra (e.g. [2]).

Durational information is also important. Earlier acoustic phonetic studies of stop and sonorant POA contrasts have measured F2 transitions and / or used locus equation metrics to characterise differences in place of articulation in a range of Australian languages, including Yindjibarndi (6 place contrasts) and Yanyuwa (7 place contrasts) (e.g [3,4]).

The strong tendency to preserve place of articulation is evident in heterorganic consonant clusters. In previous electropalatographic (EPG) analyses of Warlpiri, Arrente, and Iwaidja, there was evidence of temporal coproduction but relatively limited spatial modification of apical nasals in N–C sequences. Nasals are also longer in these sequences than has been observed in other languages. It was hypothesized that this is one strategy that is employed to preserve place contrasts [5].

One of the main cues to nasal place of articulation in VN sequences is the vowel transition as well as the spectral properties of the nasal murmur itself [6]. In many of the world’s languages, nasализation is also evident throughout the vowel transition in VN sequences. This effectively reduces the strength of spectral cues to place of articulation in the vowel transition even though the latter serves as the major cue to place of articulation in syllable-final nasals [7]. The transition between vowel and nasal murmur in VN syllables is often not as abrupt as in NV syllables, although the information signaling nasal place of articulation may be syllable-independent [2,6]. In other words, transitions into and out of the nasal murmur are equally important in cueing place of articulation regardless of whether the nasal is syllable-final or syllable-initial.

Studies of POA oral stop contrasts in Australian languages suggest there may also be a level of syllable-independence. POA in CV versus VC sequences for Australian English were compared with comparable sequences from Arrente, Yindjibarndi and Yanyuwa and it was found that VC transitions varied as much as CV transitions in the Australian indigenous languages. By contrast, English CV transitions were much more tightly controlled whereas VC transitions tended to be highly variable. It has been claimed earlier that consonants in Australian languages tend to be strengthened in “post-tonic” contexts. In other words the vowel transition information in VC contexts (where the V is prosodically prominent) is relatively protected unlike in English where the CV transition is often longer and more spectrally sharp than the VC transition [1,4].

Vowel transitions in VN sequences in Australian languages are also somewhat protected presumably to preserve spectral cues to place of articulation [9]. Indeed, some languages of central Australia including Central/Eastern Arrente have a phonological contrast between pre-stopped and plain nasals [e.g. see [8] for an overview]. In pre-stopped nasals, there is a brief period of oral occlusion between the acoustic offset of the vowel and the onset of nasal murmur. Other Australian languages also have phonetically pre-stopped nasals that are either in free variation or in allophonic variation with plain nasals. One important consequence of this is that in VN sequences the vowel transition is less damped and spectrally more distinct, enhancing the cues to place of articulation.

Figure 1 shows some of the results of a previous study of Warlpiri and Gupupuyngu [9]. These are two languages where pre-stopped nasals are in free variation with plain nasals.

Figure 1: Frequency of plain and prestopped nasals in Warlpiri (after [9])

Figure 1 shows some of the results of a previous study of Warlpiri and Gupupuyngu [9]. These are two languages where pre-stopped nasals are in free variation with plain nasals.
Around 23% of all nasals in this corpus were phonetically pre-stopped. As is evident in Figure 1, the incidence of pre-stopping is highest (43%) after close front vowels. Other major observations are that pre-stopping is more common in nasals that are produced with a rapidly moving active articulator (i.e. dental/alveolars), and it is less common where there will be clear gestural conflict, i.e. in the case of velars, where there is conflict between the velum raising gesture to close the velar port and leaving it low to facilitate the articulatory closure. This is also compatible with the view that back nasals are viewed as less “consonantal” than other nasals [e.g. 10]. Velar transitions in most languages tend to be longer than alveolar or bilabial transitions, for example. This is usually explained in terms of the slower massive tongue dorsum articulator versus the quicker tongue tip or blade/bilabial active articulators. Furthermore [11] found that palato-velars (i.e. “front velars”) in Yindjibarndi have very long transitions (of between 90-100 ms), followed by alveopalatals (around 60 ms) with remaining vowel transitions of between 30-40 ms in duration.

In this paper, vowel transitions and durational variation in nasal murmur in nasal - obstructive sequences are examined in the Kunwinjku variety of Bininj Gun-wok (BGW)[12]. BGW is part of the Non-Pama-Nyungan language grouping of Australian languages and a member of the Gunwinyguan language family. Kunwinjku has 5 places of articulation contrasts in the nasal series, shown in Table 1 below. It is hypothesized that transition patterns will be similar to those observed for other Australian languages. With regard to murmur and transition duration, we further assume that nasals in clusters will have similar durations to singletons. This was observed in earlier studies of Warlpiri and Gupupuyngu [e.g. 9] and was linked to the need to preserve place of articulation contrasts in heterorganic sequences and furthermore to enhance post-tonic strengthening of consonants [1]. In fact [5] argue that one of the reasons why nasals are unusually long in heterorganic alveolar nasal + velar clusters in Warpiri is to lengthen and strengthen the apical gesture of the post-tonic nasal and to prevent gestural “encroachment” of the tongue dorsum gesture, thereby preventing the kind of alveolar-velar assimilation that is typically observed in /nk/ sequences in other languages such as English [e.g. 13]. We further hypothesize that in homorganic sequences (i.e. where there is a shared primary articulator and no potential for gestural conflict), we might see less durational lengthening. Finally, we look for evidence of phonetic pre-stopping in nasal sequences.

2. Method

2.1 Speakers and materials

Five speakers of Kunwinjku, recorded at Mamardawerre, an outstation of Kunbarlainjina in Arnhem Land N.T. by the fourth author of this paper contributed the data for this experiment. Words containing the five nasals and different nasal-C combinations were chosen from a wordlist in consultation with Dr Murray Garde, who has worked extensively on BGW. Where possible, the words were placed in two prosodically controlled carrier phrases so that the target words would attract semantic focus and an intonational pitch accent. In most tokens the initial syllable of the focused word carried an intonational pitch accent. For some speakers the target tokens were pronounced in separate major prosodic constituents, i.e. an intonational phrase, but for others a clear intonational break was produced after the first phrase. As a consequence, tokens were consistently in intonational phrase final position that is also the most salient prosodic context in BGW.

An example of the speech material is shown below. The words in bold font show two of the tokens that were analysed in this study. The experimental materials are written using the practical orthography that has been developed for the language.

(1) yun yime birndu, yimen bongdi.
/p'ɪŋtʊ/ /p'ɒŋtɪ/

‘don’t say ‘mosquito’ say ‘trapped’.

Table 1 Phonemic inventory - Kunwinjku. The orthographic representation of nasals is shown in brackets after the IPA symbol. (After [12])

<table>
<thead>
<tr>
<th>Peripheral</th>
<th>Apico-</th>
<th>Lamina</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral Stop (lenis)</td>
<td>p</td>
<td>k</td>
<td>t</td>
</tr>
<tr>
<td>Oral Stop (fortis)</td>
<td>p'</td>
<td>k'</td>
<td>t'</td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td>n(ng)</td>
<td>n</td>
</tr>
<tr>
<td>Lateral</td>
<td>l</td>
<td>l'</td>
<td></td>
</tr>
<tr>
<td>Rhotic</td>
<td>r</td>
<td>j</td>
<td></td>
</tr>
<tr>
<td>Glide</td>
<td>w</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Front</th>
<th>Central</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>i</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>e</td>
<td>o</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2 Recording and Analysis procedure

All recordings of the Kunwinjku speakers were carried out in the field, using a Sony ECM-MS957 Electret Condenser microphone and recorded onto a Marantz PMD690 Portable Flash recorder. The files were annotated at the word, syllable, phonemic, and phonetic levels. For the purposes of this study, the following heterorganic and homorganic clusters were analysed:/mb md mc mk/ /nt nc nk / /g4t /g4k/ /g2c /g2k/ /g3p /g3t /g3k/ /g5 (/g6)/

The onset of vowel formant transitions, i.e. the point where there was the beginning significant deviation in F2 and F3 from the vowel steady-state, and the onset and offset of nasal murmur in VNC sequences were identified from spectrograms and annotated. Nasal murmur was identified where there was considerable damping of formants together with a noticeable lack of higher formant energy during consonant closure. As the carrier phrase also included examples of singleton /n/ and /m/ nasals, some were also labelled to allow us to compare nasal murmur duration in singletons versus clusters. Only tokens that occurred in a
prosodically prominent word were included. For example, the /n/ in the phrase-initial syllable [jun] was typically in a prosodically prominent position by virtue of its position in the carrier phrase so these accented instances were included in the analysis. Vowel transition and nasal murmur duration were calculated using Emu/R [14] and compared across different places of articulation. Instances of pre-stopping and the preceding vowel environment were also noted.

### 3. Results

#### 3.1. Frequency and distribution

Table 2 summarises the distribution of nasals across the corpus. The high number of bilabial and alveolar nasals is largely due to the structure of the corpus and the inclusion of singleton nasals from prosodically accented words in the carrier phrase. Of 1051 nasals analyzed, only 71 are pre-stopped, i.e. where there is a brief period of oral occlusion between the onset of the vowel and the onset of nasal murmur. The smallest % of pre-stopped nasals are velar, and highest % are alveolar and bilabial (8%).

<table>
<thead>
<tr>
<th></th>
<th>Bilabial /m/</th>
<th>Alveolar /n/</th>
<th>Retroflex /ŋ/</th>
<th>Alveopalatal /ŋ/</th>
<th>Velar /ŋ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain</td>
<td>309</td>
<td>452</td>
<td>59</td>
<td>46</td>
<td>114</td>
</tr>
<tr>
<td>Pre-stopped</td>
<td>25</td>
<td>33</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

The proportion of pre-stopped nasals in clusters and singletons is roughly similar. There is also no clear evidence (impressionistically) that vowel transitions are less damped in cases where the nasal is pre-stopped, although this will require further investigation.

#### 3.2. Acoustic Results

Figure 2 plots the duration of nasal murmur in a) intervocalic contexts, and b) in position 1 of a NC cluster for all speakers in our corpus. All clusters (heterorganic and homorganic) are pooled. A similar pattern is observed across all speakers. Nasal murmur duration varies depending on whether the N is part of an NC cluster or not (df (1,930) F=27.22, p<0.0001). Nasal murmur is often significantly longer when part of an NC cluster than in intervocalic contexts although there is also a significant but smaller interaction between POA and context (df (4,930) F=4.96, p=0.001). Tukey’s HSD post-hoc comparisons show that bilabials, alveolars, and velars are significantly longer in clusters compared to singleton consonants. This also reflects a strong main effect of POA on nasal duration when the nasal is in both NC clusters and in singleton contexts (df (4,930) F=31.18, p<0.0001). Moreover, there is also a degree of inter-speaker variation (df(4,930) F=82.76, p<0.0001) and an interaction between speaker and nasal context (df(4,930) F=5.5, p=0.001). Tukey’s HSD post-hoc comparisons show that speakers BN and JN do not produce significantly longer nasals in NC clusters unlike the remaining three speakers.

Tukey’s HSD post-hoc comparisons also show that across the corpus, bilabial nasals are longer than either alveolar or velar nasals in singleton contexts. Bilabials are also longer than alveopalatal nasals, although differences are extremely small (around 10 ms). There is no significant difference between alveolar and retroflex nasals (p=0.05). In clusters, bilabials and velars are somewhat longer than alveolars and retroflexes. Alveopalatals are significantly longer than alveolars in NC clusters but there is no significant duration difference in other contexts.

A series of post-hoc Tukey comparisons show that nasals are consistently shorter in some homorganic versus heterorganic clusters examined in this study. Velar nasals in /ŋk/ clusters have a mean duration of 82ms compared to 126ms in heterorganic /ŋp/ and /ŋt/ clusters, although once again there is inter-speaker variation. Only three of the five speakers produce significantly longer nasal murmur duration in heterorganic versus homorganic velar sequences although the remaining speakers show strong trends in this direction. Nasal murmur in /nt/ and /mp/ homorganic clusters is not significantly shorter than in heterorganic clusters for most speakers. There were insufficient examples of heterorganic alveopalatal clusters for two out of five speakers to permit statistical analysis. Of the remaining three speakers, BN has significantly longer nasal murmur in /nc/ versus /pc/ clusters (82 vs 106ms; t = 2.97, p < 0.05).

Figure 3 plots (preceding) vowel transition duration in nasal+ C sequences for all speakers. As is evident from the boxplot, there is a significant POA effect on transition duration (df (4,2850), F=285, p<0.0001). As with nasal murmur duration, there is a high level of inter-speaker variation (df(4,285) F=20.6, p<0.0001) and a weakly significant interaction between speaker and POA (df(16,285) F=2.55, p<0.01). For four of the five speakers, alveolar, bilabial and velar transitions are somewhat shorter than retroflex and alveopalatal transitions. Alveopalatals have the longest (and most variable) transition durations across all POA combinations. Figure 3 also shows that overall, transition duration is significantly shorter in homorganic clusters than in heterorganic clusters (t=10.5, p<0.0001).
of 24ms with respective standard deviation values of 15 ms and 9ms. Velar transitions have mean durations of 31ms (SD 13ms).

A relatively simple articulatory timing model can explain the duration patterns of nasals in Kunwinjku clusters. Nasal consonants in clusters may be lengthened to avoid spatial modification due to coarticulatory influences of surrounding segments. As in previous studies (e.g. [4,5,9]) we therefore relate the additional lengthening in certain clusters to the need to maintain strong POA cues (e.g. [1,9]). There are “output constraints” restrictions because POA contrasts must be maintained even in contexts of potential gestural conflict. The additional lengthening of nasals in some heterorganic NC clusters may also be linked to the tendency observed in other Australian languages to undergo post-tonic medial strengthening [1]. The place of articulation imperative is clearly a constraint that operates in the Kunwinjku data presented in this paper.

5. Acknowledgements

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6. References