was concerned with the Khonoma dialect; six of our speakers used this dialect, and only three were first language speakers of standard Angami. The Khonoma dialect is distinct from standard Angami in many respects, but it uses the same articulatory mechanism for the voiceless nasals. In both forms of Angami there is no voiced portion towards the end of the voiceless nasal consonant. Instead, before the voicing for the vowel begins, the oral occlusion is released while air is still flowing out through the nose.

The structure of these voiceless aspirated nasals may be seen from the aerodynamic records in figure 4.9, which shows examples of each of the three voiceless nasals extracted from a frame sentence. Significant moments in time are marked with arrows in the top example. At time (1) the articulators (in this case, the lips) close, and after a few vibrations of the vocal folds voicing ceases. (In our recordings made for acoustic analysis a longer voiced portion occurred at the onset of these nasals.) The line indicating the oral airflow slopes slightly upwards after the closure, but this is probably not due to any flow but occurs because the lips are being pushed forwards into the mouthpiece. There is a short pause after the oral closure is formed, and then the nasal airflow increases slowly. This is quite different from the sharp rise at closure seen in Burmese (Figure 4.7). At time (2) the articulators open and there is a rapid flow of air from the mouth. At the same time the nasal airflow decreases, but the velum remains down so that there is still a considerable flow of air through the nose. At time (3) voicing starts, probably with somewhat breathy vibrations, as there is a high rate of airflow through the mouth, as well as through the nose. If we take it that the vowel begins at this point, then we must consider at least the first part of it to be nasalized.

A similar sequence of events may be seen in the records for the other two voiceless nasals in this language. The oral airflow on the release of the alveolar closure (at the equivalent of time (2) in the middle set of records) is particularly strong. It even causes some artifacts on the audio record which was made via a microphone held just outside the oral mask. The nasal airflow drops at this moment in time, but it still remains at about 300 ml/s. The voiceless palatal nasal at the bottom of the figure shows a far less sharp release of the.oral air. These patterns were consistent across all repetitions for all of the nine speakers

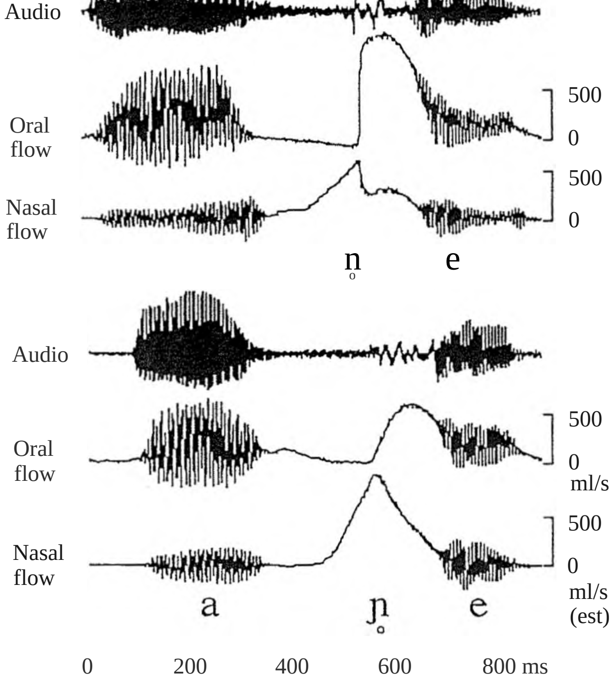

Figure 4.9 Aerodynamic records of Angami voiceless aspirated nasals. See text for explanation.

of Angami that we have recorded. Oral airflow began a little over half way through the voiceless section. Unlike the Burmese and Mizo sounds, in which there is almost always some voicing during the last part of the nasal, in Angami there was never any voicing during this part of the nasal.

Therefore these sounds are not simple voiceless nasals but are more accurately described as voiceless aspirated nasals using aspiration as a description suspect that voiceless nasals of the more familiar type were described in this fashion in order to draw attention to a parallel between voiceless nasals and aspirated stops in the phonology. Dai (1985) draws a distinction between voiceless and aspirated nasals; both types having voicelessness during the period of oral closure, but the aspirated type being followed by aspiration at the onset of the vowel. He says that the voiceless nasals of Achang have 'slight aspiration'; as such, they are neither exactly like simple voiceless nasals nor like aspirated nasals. The use of the term 'aspirated nasal' in connection with the breathy voiced nasals of KeSukuma has been mentioned above.

Acoustic structure of voiced nasals

As noted above, nasals are most frequently modally voiced. Voiced nasals are perceptually quite distinct from other speech sounds. The steady state portion of a voiced nasal consonant is characterized acoustically by a low frequency first resonance with greater intensity than the other resonances. The higher resonances have low amplitude. The overall amplitude of voiced nasals is usually less than that of adjacent vowels. During production of a nasal, air flows through the pharyngeal cavity and via the velo-pharyngeal port into the nasal cavity and out through the nostrils. The oral cavity in front of the velo-pharyngeal port forms a side chamber to this pathway. Both theoretical and empirical studies of the spectral properties of nasals indicate that this side chamber contributes a spectral zero or anti-resonance (Fant 1960, Fujimura 1962, Recasens 1983). The frequency of this zero is inversely related to the volume of the cavity, which in turn results from the position of the tongue (and other moveable tissues) in the front of the mouth. A more forward articulation of the tongue or a lower position of the tongue body will produce larger cavity volumes. More retracted articulations or a higher position of the tongue body will produce smaller cavity volumes. The frequency of the first nasal resonance and the oral zero are both higher the nearer the oral articulation is to the uvular region. The increase in the nasal resonance may be due to the decreasing size of the pharyngeal cavity as the tongue is positioned further back, and / or the size of the

ALVEOLAR	1403	167	44
RETROFLEX	1634	201	41
PALATO-ALVEOLAR	2094	233	22

velo-pharyngeal aperture itself, which is narrower when the back of the tongue is raised. The nasal cavities themselves do not vary appreciably.

There have been relatively few studies of the acoustic distinctions between nasals in natural languages, and many of those that do exist are limited to m and n (Kurowski and Blumstein 1987, Qi and Fox 1992). However, Recasens (1983) provides some acoustic data on the four contrasting nasals in Catalan. Means of the first nasal resonance from word-final nasals for 13 Catalan speakers are given in table 4.6. His estimates of the nasal zero frequency for one of these speakers are also reported.

We have made our own estimates of the frequencies of the nasal zeros in the four coronal nasals of Eastern Arremte. If the four coronal places involve shifts in only the location of the tongue contact, then the nasal zero will rise as the articulation becomes more retracted. If, in addition, tongue body position differs, then an articulation with a (presumptively) more retracted contact location but lower tongue body position might have a lower nasal zero than one with a more forward contact location.

Estimated values of nasal zeros were obtained for 139 tokens of plain (i.e. non-labialized) nasals in Eastern Arrernte from the average power spectrum computed over a 10 ms window located midway through the closure of the nasal. Following a technique analogous to that used by Recasens, the nasal zero was considered to be the largest negative peak located between Fl and F2 in the spectral display. The corresponding wide band spectrogram was simultaneously examined to verify that the chosen value coincided with the center frequency of the appropriate area of attenuated amplitude throughout the nasal. Results of these measurements are reported in table 4.7. A highly significant effect of place was found in a one-way analysis of variance, $F(3,136) = 66.0$, $p < 0.0001$. All place pairings are significantly different at better than the .05 level by Fisher's PLSD test (adapted for unequal cell sizes).

If only contact location was involved in the more forward coronal place quencies than the dental or alveolar nasals, as expected. The palato-alveolar has a significantly higher value than the retroflex. While we do not know the specific nature of the Arrernte nasal articulations used by this speaker, the observed values would be consistent with the palatal being laminal and the retroflex apical as we saw for Arrernte plosives in chapter 2, figure 2.12.

Despite these acoustic differences, nasals with different places of articulation are poorly discriminable one from another on the basis of the voiced steady state portion isolated from the transitions which might precede or follow it (Malecot 1956, Nord 1976). Coarticulation with adjacent vowels also may have a strong influence on the perception of place of articulation for nasals (Zee 1981, Kitazawa and Doshita 1984). In particular, these studies suggest that high front vowels present an environment in which bilabial nasals are heard as if produced with a further back articulation. This effect may have contributed to the change of Classical Latin m to n in Old French in monosyllabic words, such as *rem rien, meum mien* (final nasals were lost except in monosyllables, and later changes have resulted in nasalized vowels rather than final nasals), and to the reduction of the number of contrasting final nasals in Chinese (Zee 1985).

4.3 Partially Nasal Consonants

Since the raising or lowering of the velum is independent of the movements of (most of) the oral articulators, an essentially static position of these articulators can be maintained while the position of the velum is changed. In this section we will discuss the existence of sounds which could be described as being partially nasal, that is, the velic position is changed during their production so that for part of their duration they are nasal and for part of their duration they are oral. It is possible to imagine a much larger number of potential categories of partially nasal consonants than those which seem actually to have been observed. If we consider just those consonants produced with the pulmonic airstream, then the observed partially nasal consonants fall into only four classes. These are prenasalized stops (including affricates), prenasalized fricatives, marginal. Although voiceless stops preceded by nasals in Zulu may be pronounced as ejectives (e.g. class 9/10 prefix /N7 + stem /-pala/ "antelope" = [imp’ala]) it is probable that the resulting strings do not have the structure of prenasalized ejective stops, since the function of the prothetic vowel i- found here seems to be to provide a syllable nucleus for the nasal to attach to. This would be unexpected before a unitary prenasalized segment, and the nasal may be taken as simply a coda consonant in this initial syllable. Prenasalization does occur with clicks, but we will postpone discussion of this type of sound until chapter 9.

Prenasalized stops

The similarity in the mode of production between plosives and nasals results in a connection between nasals and stops in the phonology of many languages. In many cases a sequence of a nasal and a stop must be homorganic; for example, in English, nasal + stop sequences within a morpheme must be homorganic. In such a sequence the nasal portion is terminated and the stop initiated simply by raising the velum. A change in laryngeal setting may also occur during the sequence. It has often been argued that similar gestural sequences in some languages should be treated as unitary segments, particularly if they occur in syllable-initial position. In this case, these segments are known as prenasalized stops, and are often notated by a superscript nasal symbol preceding the stop symbol, i.e. as ^{m}b, ^{n}d, 1g etc., although where no ambiguity exists it is customary not to use superscripting but to simply write a nasal and a stop symbol, viz mb, nd, gg. This raises the question of whether there is a phonetic distinction between prenasalized stops and nasal + stop sequences. (Note that we are here concerned only with whether phoneticians should distinguish between prenasalized stops and nasal + stop sequences not with the question of the phonological representation of such a distinction.) The discussion can also be taken to apply to prenasalized affricates and fricatives, but for convenience we will confine our examples to stops.

On the face of it, it would seem that we need to make such a distinction,

Figure 4.10 Spectrograms of Sinhala words contrasting 'prenasalized stop' in ia.nda 'blind' and heterosyllabic nasal + stop sequence in lan.nda 'thicket'.

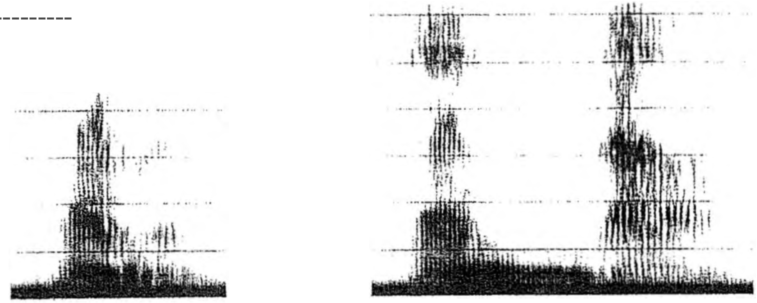

Figure4.11 Spectrograms illustrating single and geminate nasals in Sinhala in the words psena 'question' and pamna 'jumped'.

given that there are reported to be languages which distinguish between prenasalized stops and nasal + stop sequences. One frequently cited example is Sinhala (Jones 1950, Feinstein 1979). The contrast referred to this way is illustrated by pairs of examples such as the words normally cited as landa 'thicket' and la^{n}da 'blind'. Spectrograms of these words are provided in figure 4.10. We measured the duration of the interval from the onset of the oral closure for the nasal to the burst of the stop in several such pairs in recordings of two Sinhala speakers. For both speakers the mean duration of this interval in the so-called prenasalized stops was close to 100 ms. For one speaker the contrasting sequence was twice as long, and for the second closer to three times as long, 275

Figure 4.12 Spectrograms illustrating 'prenasalized stop' and geminate nasal r stop in Fula in the words waandu "monkey' andhinnde 'steamer'.

ms. The additional duration is added in the nasal portion, resulting in a nasal of comparable duration to a geminate nasal, as may be seen from the Sinhala examples of single and geminate nasals in figure 4.11. Note also that the 'prenasalized stop' in la^{n}da is of comparable duration to nasal + stop durations in other languages, such as English, where word-medial nasal + stop clusters have durations in the range 90-80 ms according to Vatikiotis-Bateson (1984) and Lisker (1984). On a phonetic basis at least, this contrast in Sinhala is more appropriately described as a contrast of single versus geminate nasals followed by stops, that is [mb, nd] vs [mmb, nnd], etc. The phonological difference between these is principally that the geminate nasals are heterosyllabic, but the single nasal + stop sequences form a syllable onset (Cairns and Feinstein 1982).

There is a similar contrast in Fula, but whereas in Sinhala nasal + stop elements only occur word-intemally, Fula prenasalized stops may appear word-initially. However, the longer nasal + stop sequence does not occur in initial position. Fula examples are illustrated in figure 4.12. As in Sinhala, we feel that the phonetic difference between these examples is best described as one between single and geminate nasals preceding a homorganic stop. The phonological patterns of Fula certainly support such an analysis: for example, when a suffix beginning with a prenasalized stop is added to a stem with a final consonant, the resulting form has a longer nasal portion (Arnott 1970, McIntosh 1984). Examples of this suffixation process are given in table 4.8.

In our recordings of Fula these 'geminate prenasalized stops' do not have much greater duration than might be expected from concatenation of a single nasal and a stop in some other language. And our measurements on a number of words with non-geminated prenasalized stops from two speakers showed that the total duration of the nasal and stop portions was in the range 45-100 ms, with a mean close to 60 ms.

Table 4.9 Mean duration of medial prenasalized consonants and selected other consonants in Fijian

	MEAN		
Prenasalized stops: 11 *speakers from three dialect areas*			
mb	132	22.2	62
nd	131	23.8	63
nd	114	25.5	65
og	114	32.6	65
Other medial consonants: 6 Standard Fijian speakers only '			
t	125	19.5	24
k	116	30.1	24
1	117	12.3	21

It might be argued that the shortness of this duration is evidence for a distinction between a prenasalized stop and a nasal + stop sequence. Herbert (1986), in his monograph on prenasalization, suggests that the phonetic characterization of a prenasalized consonant is precisely that it is a sequence of homorganic nasal and non-nasal elements that are approximately equivalent to the duration of 'simple' consonants in the same language. By implication, this means that a nasal + stop sequence would be longer than a simple stop. We feel that this view rests on false assumptions and, furthermore, does not take into account the variability in timing of segments both within and across languages.

As Browman and Goldstein (1986) have shown, the sequences mp, mb in English do not necessarily have any longer acoustic or articulatory durations than the single segments p, b, m. They also show that the timing of these English bilabials is very similar to that:which they find in word-initial p, m, mb in the KiVunjo dialect of KiChaka, where mb is usually analyzed as a prenasalized stop. Similarly, in Fijian the acoustic duration of prenasalized stops (Maddieson 1990a, Maddieson and Ladefoged 1993) is very comparable to that of other consonants in medial position as the data in table 4.9 shows. But in measurements from a KeSukuma speaker intervocalic voiced bilabial cording to linguistic environment and speech style. In many Bantu languages, this kind of gestural economy produces a lengthening of a preceding vowel, which extends into the time period 'vacated' by the compression of the nasal + stop. The process operates to different degrees in different Bantu languages; more in LuGanda and CiYao, less in KeSukuma and Runyambo (Maddieson and Ladefoged 1993, Hubbard 1995). In Austronesian and Australian languages with prenasalized stops such vowel lengthening has not been observed.

Voicing control in nasal + stop sequences

Another reason, apart from the durational considerations discussed above, for not treating 'prenasalized' segments as distinct elements from the phonetic point of view is the independent control of voicing within the sequence. In most languages that have been said to have prenasalized stops only voiced sequences occur. However, in those languages where the stop component may be either voiced or voiceless the nasal component of the sequence is generally voiced regardless of the voicing state of the stop (Herbert 1986). Thus, in many Bantu languages such as KeSukuma (Batibo 1976) there are both 'voiced' and 'voiceless' prenasalized stops. In KeSukuma the voiceless prenasalized stops are quite strongly aspirated, as illustrated in the aerodynamic records in figure 4.13 (see Maddieson 1991 for further discussion), and this is true for most of the related languages. In phonetic terms the voicing difference between such pairs lies not in the nasal but solely in the stop. In other words, the voicing state is actively changed in the middle of sequences such as mp, nt, rjk. Although nasal segments themselves are usually voiced, a change of voicing within a unitary segment is quite exceptional.

It should not be thought that aspiration necessarily accompanies voiceless prenasalized stops. The distinction between the two series of prenasalized stops in the Hmong dialects of Thailand has sometimes been reported as a