

There is, however, another possibility and that is that in order to produce the required phonological contrast of oral and nasal vowel *after* a nasal which the new phonological situation requires, a start must be made on the velic closure *during* the nasal to avoid nasalization spreading to the vowel when an oral vowel follows. In this view the measured difference between the newly derived and original nasals is a coarticulatory effect. Articulatory and aerodynamic data from other languages where oral and nasal vowels are in contrast after nasal consonants, such as French, lend plausibility to this idea. In a cineradiographic study of a Parisian French speaker, Rochette (1973) found that the velum typically does not reach such a low position in a nasal preceding an oral vowel as it does in one preceding a nasal vowel. Also before an oral vowel the velum has usually been raised most of the way towards its maximum height before the release of the oral closure for the nasal occurs. Measurements of velo-pharyngeal opening from a fibrescopic study of a Swiss French speaker (Benguerel, Hirose, Sawashima and Ushijima 1977) indicate that there is a considerably smaller maximum opening of the velic aperture for the nasal in the syllable *na* than for the nasal in the syllable *na*, and that the duration of the opening gesture is also substantially shorter. The data in Cohn (1990) shows that nasal consonants in French have lower airflow before an oral vowel than before a nasalized vowel. Her records of the distinction between *ne nez* 'nose' and *ne nain* 'dwarf' are shown in figure 4.1.

Aerodynamic records of a pair of contrasting words from our own investigations with an Acehnese speaker are shown in figure 4.2. These exemplars are representative of at least five repetitions of these words recorded as part of a set of data including all articulatory places (Long and Maddieson 1993). In *t<sup>h</sup>ania* 'sea-mew' (a species of gull) there is an intervocalic plain bilabial nasal. The duration of the labial closure can be seen from that portion of the audio waveform and the oral flow traces in which the amplitude is low. Nasal flow increases markedly during this interval, and remains elevated for two or three vibrations of the vocal cords (about 30 ms) during the following vowel. Oral pressure is only slightly elevated while the lips are closed. (The oral pressure was recorded by means of a small tube inserted between the lips, and therefore does not show the increased pressure associated with the initial stop.) In the lower panel the contrasting pattern for the other type of nasal is shown. To

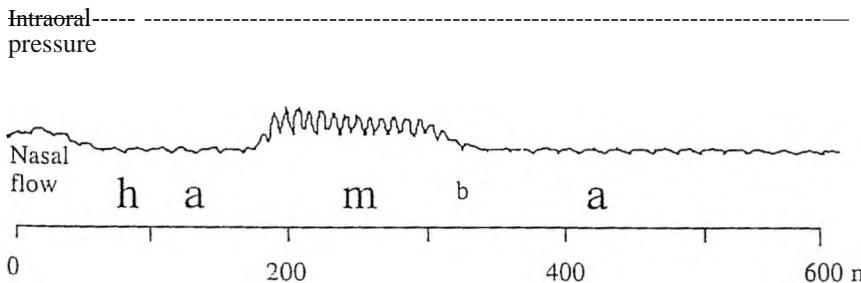
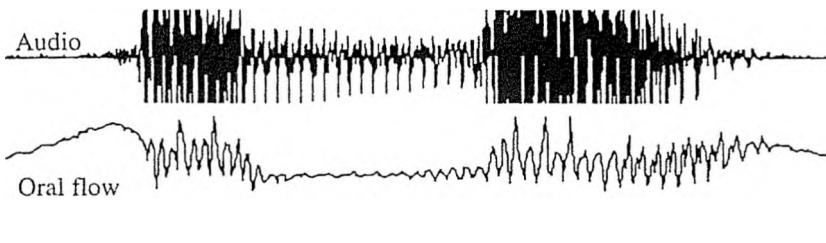
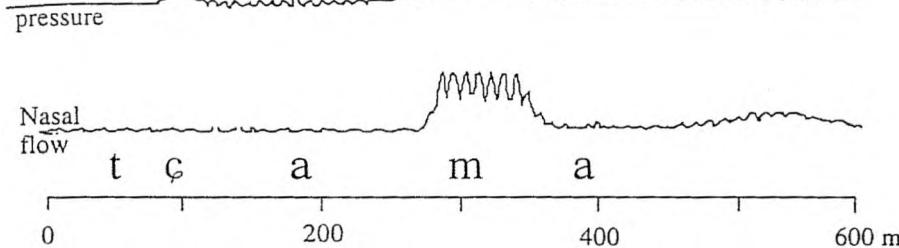


Figure 4.2 Aerodynamic records of Acehnese tqama 'sea-mew' and ham<sup>b</sup>a 'servant'.

airflow, especially at the offset of the oral closure. Thus velum lowering begins just as oral closure is made and the velum begins to be raised before oral release. The onset of this closing movement can be judged to occur about 40 ms before oral release by noting the time at which nasal flow begins to decline, and the intra-oral pressure increases.

We will call nasals of the second type orally released nasals. From these records, as well as from the experiment briefly reported by Durie (1985), we infer that the mechanism for producing such orally released nasals and preventing the spread of nasality to the following vowel involves lowering the velum to a lesser degree than in the ordinary nasals, as well as timing the whole velum-lowering gesture to coincide quite precisely with the duration of the oral articulation involved. Perhaps to permit time for this precise timing to be executed, the duration of the oral closure is lengthened in comparison with 'ordinary' nasals. The newly derived nasals in Acehnese and other languages mentioned by Durie (1985) may therefore differ from the older nasal segments in these languages simply because they are followed by oral vowels. In other words, the measurable differences in the nasals reflect a coarticulatory phenomenon like that which has been observed in nasals before oral and nasal vowels in French. Acehnese differs from French in the strictness of its requirement that the following vowel be entirely oral, but not in any other way. At this time we continue to believe that no linguistically distinctive use is made of nasals which differ in manner of articulation of the velum.

## 4.2 Laryngeal activity in nasals

In the great majority of languages all the nasal segments are produced with modal vocal fold vibration. However, a number of languages do employ nasals with different phonatory settings. In addition to modally voiced nasals, nasals occur with breathy voice, creaky (or laryngealized) voice, and with voicelessness due to open vocal folds. As with stops, there are substantial differences between languages in the relative timing of the oral and laryngeal gestures involved. We do not know of a language with four series of nasals differing in phonation type, but several Southeast Asian and North American

VOICED  
BREATHY VOICED

kumar      'boy'  
kumar      'potter'

sunar      'goldsmith'  
d3unai      'moonlight'

languages have three. Examples from Jalapa Mazatec exemplifying modally voiced, voiceless and laryngealized nasals are given in table 4.1.

Languages with three series of contrasting nasals are comparatively rare. More commonly, a language has only one series of nasals in addition to the modally voiced ones; this second series being either breathy voiced (e.g. Hindi, Marathi, Newari), or laryngealized (e.g. Montana Salish, Kwakw'ala, Stieng Nambiquara) or voiceless (Burmese, Hmong, Iaai). Usually every voiced nasal has a corresponding nasal in these other series, although in some languages the voiceless, breathy or laryngealized nasal series has fewer members than the voiced series. For example, the Zhufhoasi dialect of IXu (Snyman 1975) has plain voiced, laryngealized and breathy voiced nasals at the bilabial place of articulation, but only voiced nasals at the alveolar and velar places of articulation. Jino (Gai 1981) has voiced and voiceless velar nasals but only voiced bilabial, alveolar and palatal nasals. As shown in table 4.1, Mazatec lacks laryngealized palatal nasals.

Contrasts between modally voiced and breathy nasals in Hindi are illustrated in table 4.2 and figure 4.3. Dixit (1975) has studied this contrast in detail in his own speech. He showed that the breathy voiced nasals (which he calls 'aspirated nasals') have a shorter oral closure duration than their modally voiced counterparts. After the closure is formed, the initial portion of a breathy voiced nasal has modal voicing. The glottal opening gesture for breathy voice starts in the middle of the closure period some 40 ms before oral release. The peak of this glottal opening gesture occurs 30-40 ms after oral release, and 80-90 ms of 'voiced aspiration' is observed at the onset of the vowel. Dixit's photoglottographic data shows that the vocal folds open about as far as they do during an intervocalic h. Vocal cord vibration continues throughout the duration of the glottal gesture. Our observations generally agree with the pattern that Dixit reports. In the breathy nasal in figure 4.3 a short period of modal voicing occurs at the beginning of the nasal before breathiness begins, indicated by the greater noisiness in the signal and less well-defined resonance

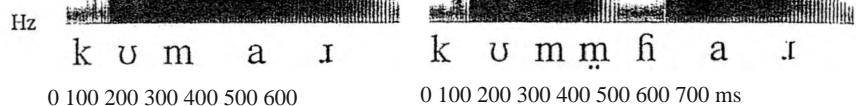
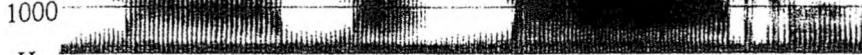


Figure 4.3 Spectrograms illustrating modally and breathy voiced nasals in Hindi in the words *kumar* 'boy' and *kumar* 'potter' respectively. The transcription below the spectrogram shows additional phonetic detail.

peaks. It is difficult to determine the precise time of the oral release but the duration of breathy voicing is about 100 ms in total and the sequence is voiced throughout. Oral and glottal gestures for intervocalic breathy voiced nasals in Hindi are thus coordinated in a similar way to those for breathy voiced stops, as discussed in chapter 3.

In Tsonga breathy voiced nasals the amount of vocal fold separation is typically much less than in Hindi, but the timing of oral and laryngeal gestures seems similar. In an aerodynamic study of six speakers Traill and Jackson (1988) report that nasal airflow is the same in the early part of both modal and breathy voiced nasals, but the mean peak airflow before the release is 11 ml/s higher in breathy voiced nasals. In their data, 25 ms after a breathy voiced nasal is released the oral airflow in the following vowel is 20 ml/s higher than after a modally voiced nasal, and 75 ms after release it is still 12 ml/s higher. A spectrogram of Tsonga modal and breathy voiced nasals is shown in figure 4.4. We have also observed other differences between languages in voicing and in the degree of breathiness that accompanies breathy nasals. For example, Marathi breathy nasals sound more breathy than those in Newari (Ladefoged 1983), and in Lianchang Yi breathy nasals in initial position have a voiceless onset which extends for about one quarter to one third of their duration. The 'aspirated nasals' of northern varieties of KeSukuma (Maddieson 1991) and of Kwanyama can also be produced with sufficiently open vocal folds so that for part of their duration they are voiceless.

In addition to Mazatec (Table 4.1), we have heard laryngealized nasals in a number of other Native American languages. In Kwakw'ala (exemplified in table 4.3) the laryngeal constriction gesture seems to be centered at the same point in time as the oral closure, so that creaky voice characterizes the middle



Hz

n ai lan ai r u

0 100 200 300 400 500 600 6 100 200 300 400 500 600 700 ms

Figure 4.4 Spectrograms of Tsonga modal and breathy voiced nasals in the words nala 'enemy' and naru 'three', as spoken by a male speaker.

Table 4.3 Words illustrating voiced and laryngealized nasals in Kwakw'ala

	BILABIAL		ALVEOLAR	
VOICED	mixa	'sleeping'	naka	'drinking'
LAIVNCEAUZED	mumuxdi	'balsam tree'	nala	'day'

part of the nasal, but in other languages the laryngeal constriction occurs at the beginning or the end of the nasal. In some cases the glottis may be entirely closed, temporarily preventing airflow through the nose. Figure 4.5 shows an utterance from Columbian Salish that includes two syllabic laryngealized nasals (and also a voiceless nasal). Note that the first of the laryngealized nasals shows strong, almost periodic, low frequency pulses, while the second appears to have quite turbulent airflow. In both cases, the laryngealization of the nasal culminates in a glottal stop. Phonologically speaking, in this language the laryngealization of the nasal could be regarded as an effect of a glottal stop segment, or the phonetic sequence could be labeled a 'postglottalized' nasal. By contrast, the laryngealized nasals in Montana Salish could be regarded as preglottalized nasals, in that they usually have a strong glottal constriction at the beginning of the nasal. Two speakers' productions of smu 'mare' are shown in figure 4.6. Sometimes the glottalization takes the form of a complete glottal stop followed by a nasal with what appears to be modal voice, as in the case of the speaker on the left of the figure; at other times there is a nasal which is almost entirely creaky voiced, as for the speaker on the right of the figure.

ʔ m̩ m a l ?

0 100 200 300 400 500 600 700 800 ms

Figure 4.5 Spectrogram of the Columbian Salish word /nm̩pa/ 'lukewarm', containing two laryngealized nasals. The transcription below the spectrogram shows additional phonetic detail.

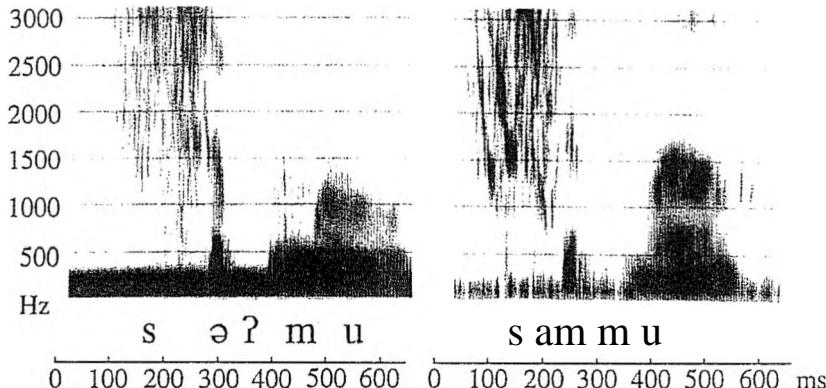


Figure 4.6 Spectrograms of smu 'mare' as pronounced by two speakers of Montana Salish. In both cases there is an epenthetic a separating the first two consonants in the initial cluster.

When there are sequences of glottal nasals, as in snmne 'toilet' the second nasal is better described as having superimposed creaky voice, so that in a narrow transcription this word is usually [sa'nm'ne]. In final position in Montana Salish the glottal constriction may be followed by a very creaky nasal or even one that is voiceless. Traill (1985) describes globalized nasals in !X6o that "are invariably pronounced with a glottal stop preceding the nasal." He also notes that the duration of the voiced portion of the nasal in this position is shorter than it is in the plain nasals. Kashaya (Buckley 1990, 1993) places the glottal

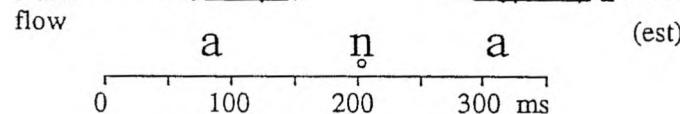


Figure 4.7 Aerodynamic records of the Burmese word (a) na 'nose' that are typical of five of the six Burmese speakers.

Table 4.4 Words contrasting voiced and voiceless nasals in Burmese

	BILABIAL	ALVEOLAR	PALATAL	VELAR	LABIALIZED ALVEOLAR
VOICED	ma	na	pa	iŋa	nʷa
	'hard'	'pain'	'right'	'fish'	'cow'
VOICELESS	ma	na		qa	nʷa
	'notice'	'nose'	'considerate'	'borrow'	'peel'

constriction at the beginning of the nasal when the consonant is syllable-initial, and at the end when it is syllable-final. There is obviously room for further language-specific variation in the way that these oral and laryngeal gestures are related to each other, but the documentation is not yet very extensive.

Voiceless nasals contrast with voiced nasals in several languages spoken in South-East Asia. Burmese examples are shown in table 4.4. These voiceless nasals usually have an open glottis for most of the articulation, but some voicing for the period just before the articulators come apart. They are also usually longer than voiced nasals, and have a higher FO at the onset of the vowel (Maddieson 1984b).

We have recordings of the oral and nasal airflow during the pronunciation of sets of Burmese words spoken in the sentence rja\_\_\_\_\_ ko ye ne te 'I write \_\_\_\_'. A typical recording of a word beginning with a voiceless nasal consonant is illustrated in figure 4.7. Six Burmese speakers, three men and three women, all from Yangon, Myanmar, were recorded in this way, each of them saying the

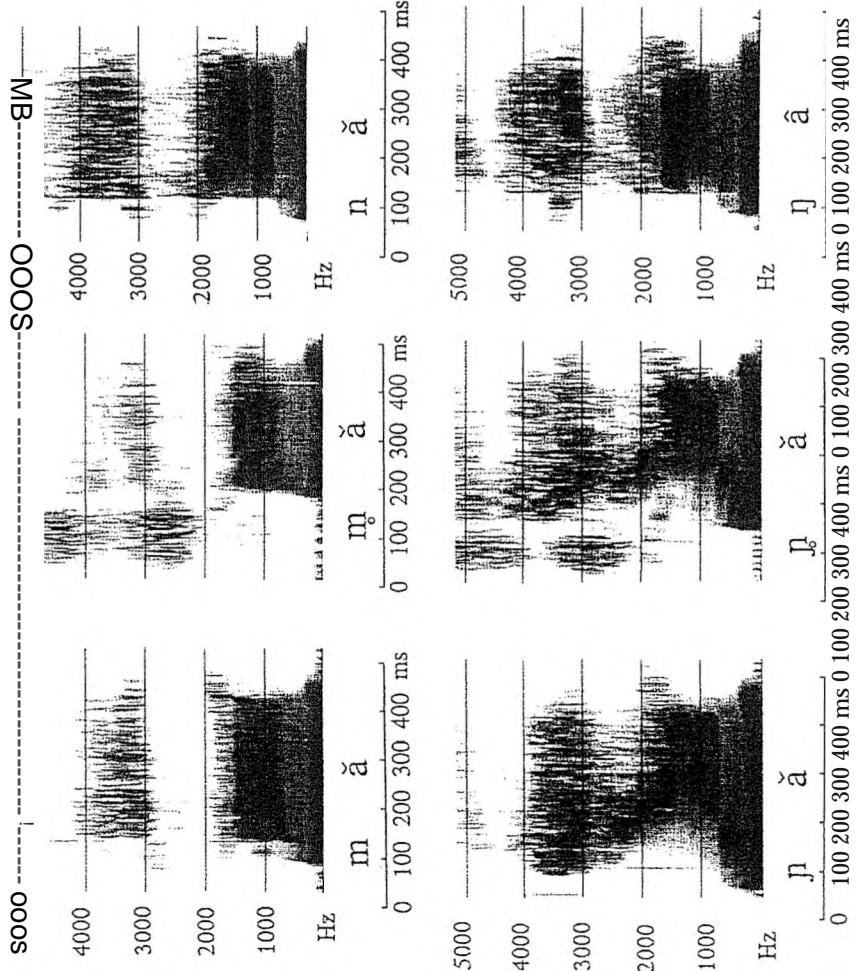




Figure 4.8 Spectrograms illustrating five pairs of Burmese voiced and voiceless nasals. The words are those listed in table 4.4.

four words in the frame sentence once. As discussed in chapter 3, there is a high volume of nasal airflow (often above the limits of the transduction system, as in the figure) suggesting that these nasals are produced with a wide open glottis and might therefore be characterized as aspirated. Measurements indicated that, for all these speakers, in the last part of the oral closure there is substantial voicing, often amounting to almost a quarter of the duration of the segment. We also recorded the speech of three female speakers of the Hmar dialect of Mizo, another language that has voiceless nasals similar to those in Burmese, finding essentially the same situation.

Ladefoged (1971) and Ohala (1975) suggest that an early onset of voicing helps to distinguish one voiceless nasal from another by making the place of articulation more apparent. This is because the voiced offglide from the nasal into the vowel displays formant transitions that are characteristic of each place of articulation. Dantsuji has shown that, in addition, the voiced portions of the voiceless nasals in Burmese "include significant cues which can distinguish points of articulation." (Dantsuji 1986: 1). There are also indications that the spectra of the voiceless portions differ; for example, bilabials may be distinguishable from voiceless nasals made at other places because of greater relative energy in the lower frequency range in the voiceless portion (Maddieson 1983). The spectrograms in figure 4.8 illustrate the contrast of voiced and voiceless nasals in the Burmese words in table 4.4. Here differences in transitional movements during the noise portion of the voiceless nasals distinguish places of articulation quite well. Note also that for these words spoken in isolation there is usually very little voicing before the release of the voiceless nasals.

It might seem that the short voiced portions at the end of Burmese and Mizo voiceless nasals could be regarded as simply part of a transition universally required by voiceless nasals. But this is not the case. Angami, another Tibeto-Burman language, spoken in the state of Nagaland, in northeastern India, has a very different series of voiceless nasals. Examples of the contrasts among Angami voiced and voiceless nasals are given in table 4.5.