

*Investigating Universals of Sound Change: the Effect of Vowel Height and Duration on the Development of Distinctive Nasalization*

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**X.1 Introduction**

In a series of studies in the 1970s, a small group of linguists investigating possible universals of sound change (Schourup, 1973, Chen, 1972-, Chen & Wang, 1975, Lightner, 1973, Ruhlen, 1973, and Foley, 1977) examined in detail the development of distinctive nasalization, i.e. VN >  $\tilde{V}N$  >  $\tilde{V}$ , across languages. All concluded independently that the development of some or all parts of the distinctive nasalization process occurs preferentially in the context of low vowels before spreading gradually to mid and then finally to high vowels when adjacent to nasal consonants, as in (I):

(I) Vowel Height Parameter (VHP)

low >> mid >> high

At first glance, such a claim seems uncontroversial, and appears to have been accepted by many linguists, both phonologists (e.g. Dinnsen, 1981) and phoneticians (e.g. Beddor, 1993) alike - on the basis of what appears to be very convincing textual/philological, cross-linguistic/typological, phonological and phonetic evidence. However, on closer inspection the reported bases for such a claim are found to be problematic - as reported by Hajek (1992, 1993, 1997) and below. We hypothesize instead the existence of two competing and differently motivated universals and provide cross-linguistic and phonetic evidence in support of such a hypothesis.

**X.2 The Philological Evidence: Old French**

Fundamental to the VHP are reported historical developments in French - cited in all studies on the development of distinctive nasalization published in the 1970s. Chen's schematized account, only very slightly modified and given in Figure (1), is typical regarding the spread (marked by +) of distinctive nasalization in Old French in the context VN:

a	e	ai	ei	o	oi	i	u	
+								End 10th/11th C
+	+	+						First half of 11th C
+	+	+	+					Mid 11th C
+	+	+	+	+				Mid 12th C
+	+	+	+	+	+			End 12th/13th C
+	+	+	+	+	+	+		Mid 13th C
+	+	+	+	+	+	+	+	14th C

Figure X.1. Chronology of Distinctive Nasalization in Old French. Source: Chen (1973: 187) based on Straka (1955: 255)

The Old French evidence cited in support the suggested VHP has been drawn primarily from Pope (1952) and Straka (1955) who, like many other French linguists, consider the gradual spread seen in Figure X.1 of increased levels of contextual nasalization to be inferrable from the behaviour of Old French /VC/ and /VN/ in

assonating rhyme. Pope and Straka are in general agreement that by the end of the 10th century  $aC$  and  $aN$  no longer appeared together in assonance, i.e.  $aN$  is rhymed only with other examples of  $aN$ , and  $aC$  is similarly rhymed only with  $aC$ . Only slowly over the following three centuries did the same effect extend to the rest of the vowel system according to height, as suggested in Figure X.1. Pope and Straka, like others, conclude that the failure of  $VN$  and  $VC$  to assonate, affecting low vowels first before extending over time to affect increasingly higher vowels, is the result of the blocking effect of increased levels of contextual nasalization, i.e.  $\tilde{a}N \neq aC$ , then  $\tilde{e}N \neq eC$ , and so forth.

Unfortunately, the vowel height schema in Figure X.1 has little or no factual basis. There is absolutely no textual evidence which allows us to posit the nasalization of low  $aN$  before that of mid  $eN$ . Consequently, some linguists, e.g. Straka (1955), are forced to presume that  $a$  was necessarily nasalized before  $e$  for physiological reasons, i.e. as a result of universally greater velic opening on the former (see below). Recent detailed statistical analyses of the distribution of assonance in Old French by Reenen (1985, 1987) also fail to confirm the vowel height hypothesis of nasalization in Old French. He reports  $oN-oN$ ,  $iN-iN$  and  $uN-uN$  pairing to be under way at the same time in the 12th century, rather than chronologically separate as indicated in Figure X.1. He also found assonance to be morphologically, rather than phonologically conditioned: there was a conscious grouping of so-called 'masculine'  $VN - VN$  pairs, but regular  $VN - VC$  assonance in the 'feminine' where  $V$  was orthographically the same vowel in height and quality. Such morphological conditioning cannot be accounted for by the vowel height hypothesis. In addition, the gradualist hypothesis makes the prediction that the frequency of nasalized vowels will increase over time, as nasalization spreads along the height parameter. In terms of assonance, such a claim will manifest itself by an increase in the proportion of  $VN$  assonating only with  $VN$  in later texts, as progressively more vowels before  $N$  are affected by nasalization. However, Reenen (1987) found the inverse to be correct in a sample of 11th-14th century texts: common in the earliest texts (11th-12th centuries),  $VN-VN$  pairing declines until it disappears completely two centuries later.

Given these facts and many others not cited here (Hajek, 1993 for details) we are forced to conclude that a pattern of gradual height-conditioned vowel nasalization in Old French cannot be shown by changing patterns of assonance in early French texts. Indeed, as Reenen (1985, 1987) observes, no pattern of vowel nasalization (or N-deletion) can be determined in this way.

### X.3 Other Cross-Linguistic Evidence for a Vowel Height Effect

The exclusion of Old French does not preclude the operation of the VHP elsewhere. Indeed if the VHP holds universally, as has been suggested, then where a gradual effect can be determined, it should always operate preferentially on low vowels. In reality, other cross-linguistic evidence of vowel-height conditioning of nasalization phenomena provides a mixed bag, with examples of preferential nasalization and N-deletion in the context of high vowels on the one hand and preferential low vowel effects on the other.

#### X.3.1 Low Vowels Favoured

(1) In the Romance dialects of Northern Italy, there is preferential nasalization of historically short low vowels. Historically short high-mid and high vowels are never affected. For examples, in Imolese we find  $[k\tilde{e}:na] < [ka:na] < \text{Latin CANNA 'cane'}$ ,  $[gr\tilde{e}:nda] < [gra:nda] < \text{GRANDE 'big'}$  but  $[pena] < \text{PINNA 'fin'}$   $[membar] < \text{MEMBRU 'member'}$ ,  $[l\tilde{e}ngwa] < \text{LINGUA 'tongue'}$ ,  $[ondza] < [undza] < \text{UNGULA 'fingernail'}$  (Hajek, 1992, 1997). There is clear interaction between nasalization and an earlier process of height conditioned vowel lengthening. We shall return to this very important point in later discussion.

(2) In some Eastern Algonquian languages spontaneous nasalization of reconstructed low vowel  $*/a:/$  has occurred in non-nasal contexts, e.g. W. Abenaki  $/s\tilde{a}k\tilde{o}kw/ < */j\tilde{e}ka:kwa/$  'skunk'. The remaining five vowels of the Proto-Eastern Algonquian system,  $*/i: o: e: \tilde{a}/$ , remain untouched by nasalization, although  $*/e:/$  has since shifted to  $/a:/$

(Whalen & Beddor, 1989).

(3) Hombert (1986, 1987) claims that reconstructed Proto-Bantu open /\*a, \*e, \*o/ before N are more likely than close /\*i, \*u/ to be affected by distinctive nasalization in a small set of Teke languages spoken in Central Africa. No finer distinction between low and mid vowels can be made from the data.

(4) Chen (1972 & elsewhere) claims to find extensive synchronic and diachronic evidence in support of the VHP in Chinese dialects. In a simple synchronic lexicostatistical count of oral and nasal vowels (20,829 lexical items for eleven dialects), Chen (1975) reports that for  $\tilde{V}_1 \sim V_1N$  pairs, where  $V_1$  has the same quality, but differs with regard to distinctive nasalization, e.g.  $\tilde{i}/$  vs.  $/in/$ , an inverse relationship holds between vowel height and the relative frequency of nasal vowels: the percentages for high, mid and low vowels were 10%, 12% and 24% respectively. Chen's initial hypothesis is that this distribution is accounted for by: (1) preferential nasalization of low vowels over time; (2) a tendency for nasal vowels to lower, and (3) the preferential denasalization of high nasal vowels. In order to evaluate the impact of each of these factors, Chen goes on to examine patterns of nasalization - synchronic and diachronic - in over 1200 Chinese dialects. He finds (2) and (3) not to hold as stated, but the empirical basis for (1) to be extremely strong. N-deletion where it is reported occurs in substantially more dialects after Middle Chinese /a/, the number of dialects dropping as vowel height increases. Representative figures for original /an, aŋ, əm, əŋ, uŋ/ are 414, 243, 193, 134 and 24 dialects respectively with N-deletion.

Several of these cross-linguistic examples are amenable to alternative explanation. Whilst the Algonquian and Northern Italian data are discussed in sections X.5 and X.6 respectively, specific attention is given here to the Chinese evidence, since it is often cited in support of the VHP. There is strong evidence to suggest that Chen's sample results are inadvertently biased and should, therefore, be treated with caution. First, we note that interdialectal borrowing, known to be pervasive in the Sinitic area, has not been controlled for, yet appears to have skewed results in favour of low vowel nasalization (see Entenman, 1976 for details). Second, with regard to both the synchronic and diachronic data, no consideration was given to the potentially confounding effect of secondary hardening of nasalized off-glides, e.g.  $VN > \tilde{V} > \tilde{V}\tilde{G} > \tilde{V}\eta$ . In a detailed study of Northern Italian dialects (Hajek, 1992, 1997) diphthongization and subsequent glide hardening were found to be common, especially in the context of high vowels, e.g. LUNA > [lõwna] > [lõŋna] 'moon' but LANA > [lã:na] > [lẽ:na]/[le:na] 'wool' in Bolognese. Chen's (1975) presentation of data regarding developments affecting vowels before final coronal /n/ in 129 Hebei dialects (Table 16, p.52) is, in our view, entirely consistent with this observation: full velar nasals appear only after the reflexes of historically non-low vowels, e.g. /en/, /in/, /uen/ > /eŋ/, /iŋ/, /oŋ/ respectively (but /an/ > /ã, a<sup>n</sup>, a, ε/). Chen treats the former as simple N-place shift: en > eŋ, etc.... However, not all dialects have non-low /eŋ, iŋ, oŋ/. A second group has secondarily denasalized off-glided /ei, iei, uei/ and a third has nasalized /ẽ, iẽ, uẽ/. We interpret these data in the following manner: the third group with nasal monophthongs is the most conservative. Elsewhere these nasalized vowels underwent diphthongization. Subsequent denasalization in the second group blocked glide-hardening, whilst in the first group nasalized off-glides were consonantized. If our scenario is correct, then developments in 129 Hebei dialects cannot be cited in favour of preferential low vowel nasalization, and the quantitative case in favour of low vowel nasalization is substantially reduced. We suspect too that developments in many more dialects are amenable to reinterpretation on the basis of preferential glide hardening to N after high vowels.

Finally, it is also to be noted that the analysis of diachronic patterning in Chinese is affected by the particular Middle Chinese reconstruction (of which there are many) adopted: Hess (1988) in a study of the development of nasal vowels in Wu dialects of Chinese, used a reconstruction different from the one used by Chen and found, unlike Chen, that low /a/ and low mid /ε, ɔ/ before N could not be distinguished in terms of preferential nasalization.

### X.3.2 High vowels favoured

Counter-examples (cf. Hajek 1997) to the universal operation of the VHP include:

(1) In Chamorro a phonological rule of contextual nasalization before or after /m/ always applies to high vowels, only optionally to mid vowels, and never to low vowels .

(2) In Valaisan Franco-Provençal, a phonological process of progressive nasalization after N affects only reflexes of earlier long high vowels /i: u:/, e.g. /ni:/ > /nẽĩ/ *nest* , /nu:tre/ > /nõtre/ *our*, but /nord/ > /nɔ:/ *north*, and /mal/ > /mo:/ *evil*. A similar phenomenon has been noted since medieval times in the Gallo-Roman dialects of north-west France, e.g. AMICU > [amĩ(n)]/[amẽ] *friend* but MAGIS > [mẽ] *but*.

(3) Spontaneous nasalization of word-final stressed vowels, widespread in Northern France, is restricted to reflexes of historical high vowels /i u/ only, e.g. Lat. SPICU > /e'pi/ > Picard [E'pẽj] *ear of corn*, PERDUTU > [per'dœʝ] *lost* but MALE > ['mo] *bad*, /kilo/ > [tʃi'lu] *kilo*.

(4) With regard to N-deletion, Cedergren & Sankoff (1975), in a study of the sociolinguistic spread of distinctive nasalization in Panamanian Spanish, report that loss of syllable-final N in the context [VN\$] is strongly favoured when the vowel in question is high. Mid and low vowels are reported to have an inhibiting effect on N-deletion.

(5) Chen (1975) reports two genuine counter-examples to the VHP in his study of more than 1200 dialects - whereby only high VN > high Ṽ for which he can provide no explanation. However, reanalysis of some of the very limited data provided by Chen for a handful of other dialects allows us to add at least three more: Mengzì, Kaiyuan and Huaning.<sup>1</sup> More such counter-examples may exist, but cannot be ascertained by us in the absence of more dialect data .

## X.4 Phonetic Explanations for a Possible Vowel Height Effect on the Development of Distinctive Nasalization

Cross-linguistic evidence in favour and against the VHP indicate that two contradictory tendencies of preferential high vowel nasalization and preferential low vowel nasalization manifest themselves across languages, and need to be accounted for. That different cross-linguistic patterns are reported is not surprising in a context where inconsistencies in the available phonetic evidence discussed below allow for different predictions about the effect of vowel height to be made.

### X.4.1 The Velic Opening Hypothesis

Investigators, such as Ruhlen (1973: 11), Hombert (1987: 274) and Chen & Wang (1975: 276-278), who offer a phonetic explanation for the suggested VHP, claim that the parameter has an articulatory basis in vowel height-governed differences in velopharyngeal or velic opening (VPO). Chen & Wang and Hombert note firstly that low vowels in oral contexts may be produced with an open velum in some languages. This is confirmed experimentally (see Clumeck, 1976: 344, and Ohala, 1975 for details). Furthermore, experimental results, based on fibroscopic and X-ray studies of languages such as English, Hindi and Chinese, are reported to show that the relative degree of velic opening in a vowel in nasal contexts is inversely related to increased vowel height (see Chen & Wang, 1975; Bell-Berti, 1993). Low vowels are produced with an amount of VPO far greater than that reported for higher vowels in the same nasal context.

However, these articulatory patterns alone can neither explain all the available cross-linguistic data (see below), nor is it fully consistent with other phonetic (articulatory, acoustic and perceptual) evidence.

First, the suggested correlation between velic opening and vowel height in oral contexts is contradicted by evidence of VPO in oral high vowels, as reported in Ontario French and English, North African French and variably in American English (Reenen,

1982).

Second, discussion in the experimental phonetic literature suggests very strongly that there is not for all vowels one unitary level of sufficient velic opening necessary for the phonologization of nasalization. It is implicit in the argumentation in support of the VHP that levels of velic opening are intrinsically different according to vowel height. Therefore, the level of velic opening in high vowels, even when maximum, may never approach that found in low vowels. However, phonologization at these lower levels must be possible, otherwise nasalization of high vowels could not occur. As a result, intrinsic differences in velic opening between vowels of different vowel heights should not be considered to be automatic causes of a differential process of nasalization (contextual and/or distinctive). Instead, we argue that individual velic opening targets for phonologization are best established for each vowel or degree of vowel height. Physiological and perceptual evidence support this view: muscular constraints involving palatoglottus and levator palatini activity have frequently been cited to account for vowel and vowel height conditioned differences in velum position (Bell-Berti, 1993 for details and references). Moreover, it has often been noted that high vowels seem to require far less VPO and nasal coupling to be perceived as nasal than do low vowels (House & Stevens, 1956, Maeda, 1993 and below).

Third, close examination of cross-linguistic experimental evidence does not fully support the hypothesis of a strict inverse correlation, as has often been suggested (see Ohala, 1975, Bell-Berti, 1993, Beddor, 1993 for references), between relative VPO and vowel height. We report here briefly on the results of two major cross-linguistic studies in which velic amplitude was determined by nasographic photodetection.

Al-Bamerni (1983) looked at levels of VPO in pre-nasal vowels for ten speakers (Ss) of seven languages (French [3Ss], English [2Ss], Hindi [1S], Gujarati [1S], Kurdish [1S], Arabic [1S] and Norwegian [1S]). Al-Bamerni found statistically significant differences in velic opening between high and low vowels in only five languages (French, English, Kurdish, Arabic, Norwegian). Unexpectedly, in Gujarati and Hindi, highest levels of velic opening occurred in mid-high and high back vowels /o u/. Height-conditioned differences in VPO were significant in Hindi but not in Gujarati. In both languages VPO distribution was consistent across contexts: a similar pattern was also reported in vowels after N as well as in distinctively nasal vowels. We note also that no difference in VPO between mid and high vowels was found in Hindi, Gujarati, English, or French.

Are we able to generalize for Hindi on the basis of Al-Bamerni's results? Henderson (1984) found low vowels to have greatest VPO in Hindi, whilst Clumeck (1976) found no height effect at all in Hindi in the two contexts he examined (VN and  $\tilde{V}$ ). We take the view that the variability uncovered cannot be accounted for by the Velic Opening hypothesis.

Even more inconclusive are the results of Clumeck's (1976) nasographic investigation of velic opening in vowels before N in thirteen speakers of six languages (American English [4Ss], French [3Ss], Amoy Chinese [1S], Brazilian Portuguese [1S], Swedish [3Ss] and Hindi [1S]). He found that 8/13 speakers showed no significant difference between low and high vowels. Results are even worse when VPO differences between high and mid vowels and between low and mid vowels are compared: in the former 11/13 speakers showed no difference, and in the latter 10/13 did not. Variability cuts across all languages, including American English and French, reflecting substantial inter-speaker variation.

One might argue that the above results still favour the VHP, in the sense that where a significant effect is reported, it is almost always the case that low vowel VPO is greater than that for high vowels. However, such an argument obscures the fact that the VHP also predicts that VPO will always be greater in mid vowels than in high vowels, and that nasalization of the former will always be favoured as a result. Yet the two nasographic studies cited above show little or no evidence of greater VPO in mid vowels when compared to that in high vowels. As a result, the hypothesis of a strictly universal inverse correlation between vowel height and velic opening must be rejected as empirically unproven, although a tendency towards such a correlation may be apparent in some languages, especially when the more distant categories of low and high vowels are compared.

It is perhaps also worth noting at this point that the very status of VPO as critical marker of relative vowel nasalization has been questioned by some investigators, e.g. Clumeck (1976) and Al-Bamerni (1983). It has been suggested that other articulatorily dependent correlates may turn out to be more significant, e.g. nasal airflow levels (*per* Al-Bamerni), and nasal sound pressure levels (NSPL). Both are known to increase with oral constriction, and are, therefore, substantially greater in high vowels. Indeed, some experts, e.g. Rochet & Rochet (1991) and Clarke & Mackiewicz-Krassowska (1977), do in fact consider NSPL to best mark relative vowel nasality, and conclude that high vowels are more nasalized. The latter are explicit in suggesting a strong correlation between greater NSPL in high vowels and earlier reports of their increased perceived nasality in cleft palate speech.

#### *X.4.2 Interaction between Vowel Height and Vowel Nasalization as Perceptually Motivated*

As might be expected from discussion to this point, the available perceptual evidence is also conflicting, with two regular patterns in evidence: preferential high vowel nasalization, and preferential low vowel nasalization.

##### X.4.2.1 Evidence for a High >> Low Parameter

It is well-known that the acoustic effect of velic opening does not correlate with the purported VHP in the same simple manner for all vowels. Ohala (1975), Lubker (1968) and Maeda (1989, 1993), amongst others, report that high vowels are acoustically the least able to tolerate velic opening: small levels of velic opening are reported to have a substantial effect on high vowel spectra. In comparison, at the same levels of velic opening, little spectral change is reported in low vowels. A far greater amount of velic opening is required to achieve the same degree of acoustic distortion reported in high vowels with only limited velic opening. As Ohala notes, at low levels of velic opening, nasalization is likely to be perceptually more salient in high vowels. Phonologization of high vowel nasalization will be favoured if the ability of listeners to factor out acoustic distortion decreases as the amount of distortion increases even at low levels of velic opening. Conversely, in the same situation listeners may plausibly continue to treat contextually nasalized low vowels as phonologically oral, since the lesser acoustic distortion will be more easily eliminated.<sup>2</sup> As a consequence, velic opening in low vowels will need to be markedly increased before nasalization is perceived and then phonologized. This is consistent with the observation made earlier that small amounts of velic opening sometimes reported in oral low vowels appear to have little acoustic effect, and are in most cases easily factored out by speakers.

That some sort of relationship exists between levels of velic opening and perceived nasalization is not in dispute, e.g. House & Stevens (1956), Maeda (1989, 1993), Abramson, Nye, Henderson & Marshall (1981) and Benguerel & Lafargue (1981). For each individual vowel, regardless of quality and height, perception of nasalization rises along with increasing velic opening (but see below). However, in line with the hypothesis of relative acoustic distortion, the rate of increased responsiveness varies according to vowel height: perception of low vowel nasalization, in contrast to that of high vowels, is found to rise much more slowly with increased velic opening.

Perceptual evidence, based on manipulation of both synthetic and natural speech, in support of preferential nasalization of high vowels is not lacking. House & Stevens (1956) report that in listening tests using synthetic tokens low vowels require almost three times as much velic opening as high vowels before they are identified as nasalized by American listeners. Hawkins & Stevens (1985) manipulated synthesized versions of natural (Gujarati) speech tokens. Their results show that at lowest levels of modification of the acoustic spectrum, perceived nasality of [u, i] responded most rapidly. Abramson *et al.* (1981) tested the effect of vowel height and relative velic opening on oral/nasal consonant perception in the syllable type /nV#, dV#/ using synthetic speech. Of the three vowels tested, /i, ʌ, a/, it was found that the lower the vowel the greater the amount of velopharyngeal opening necessary for the perception of prevocalic /n/.

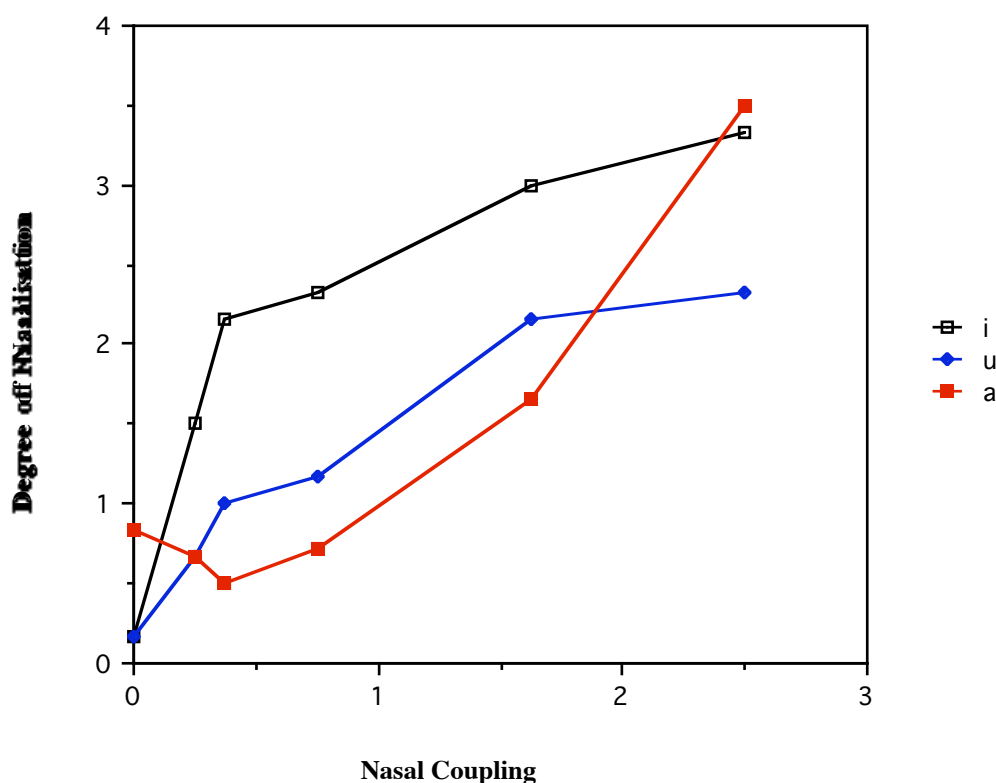


Figure X.2. Averaged Responses of Eight Subjects to [a, i, u] Synthesized with Six Degrees of Velic Opening ( 0.0, 0.2, 0.4, 0.8, 1.6, 2.5 cm<sup>2</sup>) The scale of perceived nasality along the vertical axis ranges from '0' (not nasalized) to '4' (heavily nasalized). Source: Maeda (1989, 1993)

Maeda (1989, 1993) reached similar conclusions about the interaction between vowel height and velic opening, based on perceptual evaluation of synthesized vowel nasalization. With no nasal coupling, [a] was perceived as marginally more nasal than [i, u]. However, once nasal coupling began, perception of nasalization of [u], and especially of [i], increased dramatically. Conversely, perceived nasalization of [a] decreased at very low levels of velic opening, before recovering slowly until achieving a level only marginally greater than that of [i] at peak magnitude of velic opening. At most levels of opening, [i, u] were consistently perceived as more nasalized than low vowel [a], cf. Figure X.2. In a context of general spectral 'spreading' or 'flattening' triggered by nasality, the perceptual results appear to correlate well with a simple acoustic measure of the distance in bark between two spectral prominences (dubbed N1 and N2 by Maeda, 1993) in the F1-F2 region. N1 most often corresponds to F1, and N2 is generally located in the region of F2. The measure works very well with /i a/ at all levels of coupling, and reasonably so in the case of /u/.

Abramson *et al.* (1981: 330) note that many earlier investigators found the linguistically useful range of nasal coupling in natural speech to lie between zero cm<sup>2</sup> to be little more than one cm<sup>2</sup>. If such an observation is correct, then the results of experiments using synthesized language suggest that, within the normal range of velic opening, [i] and [u] are perceptually more nasal across most points, as seen in Figure X.2.

Benguerel & Lafargue (1981) manipulated natural stimuli to find that French nasal mid vowels / $\tilde{e}$ ,  $\tilde{o}$ / were perceived as more nasal than / $\tilde{u}$ / at smaller levels of velopharyngeal opening.

The results of these perceptual tests are consistent with cross-linguistic reports that high vowels are perceptually more nasal than other vowels before N in Bengali, Chamorro and Portuguese, and that high / $\tilde{u}$ / is most nasal, and low / $\tilde{a}$ / least so in Molinos Mixtec

(Hajek, 1992, 1997).

#### X.4.2.2 Perceptual Evidence for a Low >> High Parameter

There is a smaller body of experimental work that indicates that low vowels before N are perceptually the most nasal.

Ali, Gallagher, Goldstein & Daniloff (1971) in an experiment with American subjects using edited natural tokens found that perception of deleted final N was significantly greater after low /a/ than after /u, eɪ, ε/.

Lintz & Sherman (1961) tested the perception of vowel nasality in the non-nasal contexts /CVC#/ and /CV#/ in unmanipulated hypernasal and nasal American English speech. Hypernasal tokens were predictably rated as more nasal by listeners, but overall patterns of vowel conditioning of perceived nasality were generally the same for both hypernasal and normal speech. Low vowels /ʌ, a/ were rated by listeners to be substantially more nasal than other vowels tested, for which the severity of nasality declined in the following order: ε > i > ʌ > u > u.

Bream (1968) tested the perception of vowel nasalization before N in Ontario and Standard French, as well as in Canadian English. Overall results indicate the following parameter of decreasing nasality in (Ontario and Standard) French: a, ε > i > ə. For Canadian English the ordering was in all contexts: ʌ > ε > i > i.

#### X.4.2.3 High v. Low: Explaining the Perceptual Paradox

The split in perceptual results can be explained. We suggest that both sets of perceptual results are indeed accurate, and inadvertently reflect different vowel duration effects. Interaction between vowel duration and nasalization has since been independently confirmed by Whalen & Beddor (1989) who show that increasing vowel duration triggers a corresponding rise in perceived nasalization.

All examples of preferential perception of high vowel nasality rely on synthesized speech (e.g. House & Stevens, 1956, Maeda, 1989, 1993) or heavily manipulated natural tokens (Benguerel & Lafargue, 1981). On the other hand, the perceptual evidence in favour of preferential low vowel nasalization comes from experiments in which unedited (Lintz & Sherman, 1961, Bream, 1968) or slightly edited natural speech tokens (Ali *et al.*, 1971) were used. Previously, Beddor (1993) has suggested that this division can be accounted for by stimulus differences in relative VPO. Velic opening is controlled for in synthetic speech studies, but in natural speech is likely to be greater in low vowels in accordance with the Velic Opening Hypothesis investigators of sound change in the 1970s refer to. This increased VPO favours the elicitation of nasal percepts in low natural vowels. Following this account, the implication is that the results of experiments using natural speech are more reliable - hence perception of low vowel nasality is likely to be cross-linguistically favoured for articulatory reasons. In our view, this account is insufficient, given the problems with the Velic Opening Hypothesis discussed in detail above.

In all the synthetic speech studies (Maeda, 1989, 1993, House & Stevens, 1956, Stevens *et al.* 1987, Hawkins & Stevens, 1985) vowel duration was constant regardless of vowel height. Similarly, Benguerel & Lafargue (1981) manipulated speech tokens by excising single cycles from natural tokens of /ã ẽ õ/. These cycles were then reiterated forty times to give a standard final duration (280ms.) for all manipulated vowel tokens regardless of height. Both /ẽ õ/ were perceived as more nasal than low /ã/, even though VPO was less in the former. Interestingly enough, in the same experiment Benguerel & Lafargue also included in the testbank unmanipulated copies of a reference set of /ã ẽ õ/ vowels. The set was excised from three natural speech tokens (one for each vowel) set in the same context (/t\_\_t/). This reference set was not controlled for duration, and all vowels were consistently perceived by all listeners as fully nasal, regardless of height.

In the three studies cited above in favour of preferential perception of nasality on low vowels, no attempt was made to control for vowel-dependent durational differences. That these perception studies report preferential low vowel nasalization is entirely consistent



with the following interrelated facts: (1) in the two languages investigated, French and English, low vowels are consistently reported to have the greatest duration (e.g. Rochet & Rochet, 1991, Clumeck, 1976); and (2) experimental results mentioned above and discussed below indicate that the perception of nasality is be strongly favoured by increasing vowel duration.

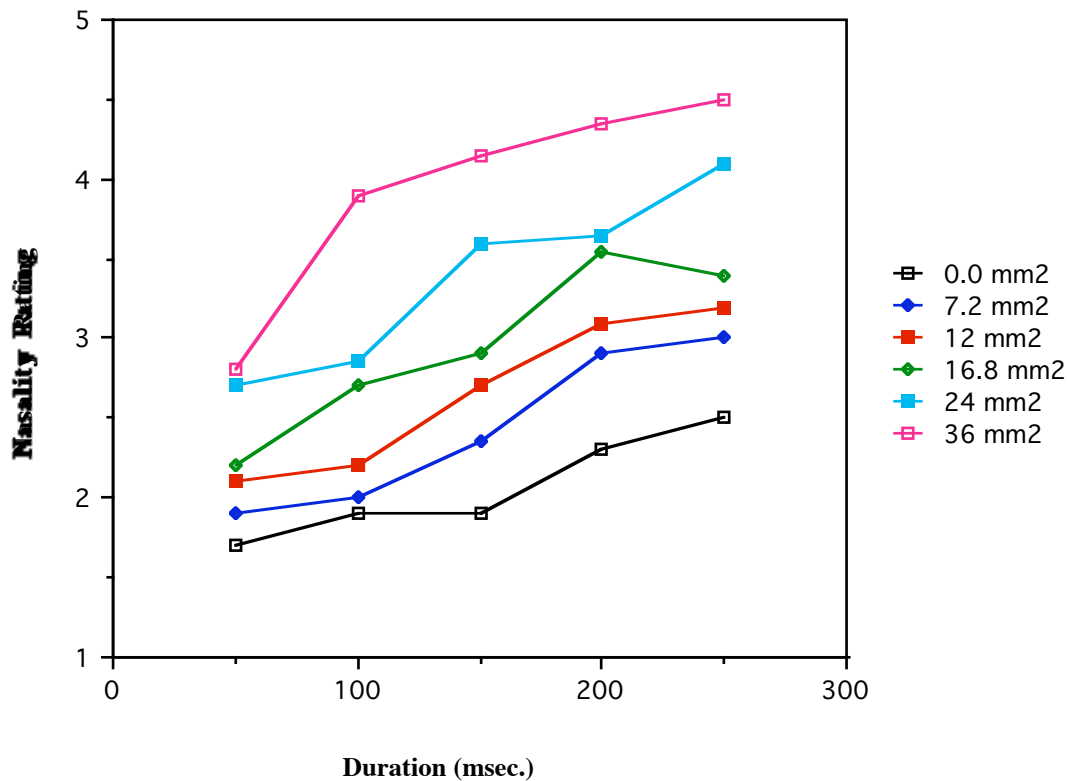


Figure X.3: Averaged Responses of Twelve Subjects to [a] Synthesized with Six Degrees of Nasalization at Five Durations. Whalen & Beddor (1989) suggest that the midpoint value '3' represents a conceivable boundary between oral and nasal vowel. Source: Whalen & Beddor (1989: 462)

In a series of experiments, Whalen & Beddor (1989) synthesized by means of an articulatory synthesizer three vowels, /a i u/, with five durations (50, 100, 150, 200 and 250 ms.) and with six degrees of velar port opening for /a/ and four for /i, u/, ranging from 'oral' to heavily nasalized. Twelve speakers of American English were then presented with tokens in randomized order and asked to rate each token from 1 ('least nasalized') to 5 ('most nasalized'). The former rating corresponded to the stimulus with zero velic coupling, and the latter with the greatest velic coupling of 36 mm<sup>2</sup>. As expected, the average nasality rating increased with greater velar port opening for all vowels, as shown for /a/ in Figure X.3. However, more significant is the finding that the nasality rating also rose with an increase in vowel duration for all vowels. These and other experiments established that the link between perceived nasality and duration was not dependent on vowel height, fundamental frequency, or amplitude.

Whalen & Beddor (1989: 472) can provide no phonetic explanation for the correlation between perceived nasality and duration, other than to suggest a poorly defined summation effect. In another experiment using modified stimuli taken from recordings of Western Abenaki, they found no evidence that oral vowels (in the absence of contextual nasalization) might be perceived as inherently more nasal as their length was increased. However, they did find that the perceived nasality of similar stimuli based on vowels in nasal contexts did correlate to some small but significant degree with duration. Their results suggest that so long as some co-articulated VPO or nasal coupling is present in the vowel, then increased duration will favour the perception of the vowel as nasalized.

Lintz & Sherman (1961), using unedited hypernasal and normal speech, found that in

phonologically oral contexts, contextually determined vowel duration differences correlated directly with the perception of nasality by American listeners on six of seven vowels tested, i.e. [i, ε, λ, α, υ, u], but not [æ] which was inexplicably perceived as strongly nasal in all contexts. As vowel duration increased according to context, e.g. before fricatives, and voiced consonants, so did perceived vowel nasality.

One issue requires clarification: in VN contexts is (1) overall vowel duration or (2) duration of nasalization on the same vowels or (3) proportion of nasalization relative to vowel duration conditioning perception of nasalization? Clumeck (1976) and Al-Bamerni (1983) both report the same general cross-linguistic pattern: individual vowel qualities with the longest overall duration (i.e. low vowels) also show the greatest period of coarticulated nasalization. In fact, the increase in duration of nasalization in these vowels is found to be disproportionate: as a result the percentage of nasalization is greater on low vowels than on higher vowels. The results of Lintz & Sherman's (1961) experiment suggest changes in vowel duration alone are sufficient to alter levels of perceived nasalization. Relative proportion of nasalization, on the other hand, seems not to be so important: where languages contrasted long and short vowels (e.g. Swedish, Norwegian, Arabic), short vowels exhibited the same or even greater proportion of nasalization. One could argue, therefore, that short vowels should be as prone to phonologization of nasalization as high vowels, if not more so. However, Whalen & Beddor's results indicate that where tokens with same temporal proportion of nasalization (in this case 100%) differ in overall duration, the longest tokens are always perceptually more nasal. This observation is further confirmed by the cross-linguistic evidence in favour of long vowel nasalization discussed below.

### **X.5 The Vowel Length Parameter: Cross-linguistic evidence in support of interaction between vowel duration and nasalization phenomena**

That duration affects the perception of vowel nasality in the manner suggested by Whalen & Beddor (1989) has long been reported, e.g. Rousselot (1924) and Straka (1955). In a recent detailed survey (Hajek, 1992, 1997) the cross-linguistic evidence of interaction between vowel duration/length and the development and spread of nasalization phenomena is found to be overwhelming. In languages with a historical or synchronic vowel length contrast before nasals, i.e. /VN/ v. /V:N/, phonologization of vowel nasalization and secondary N-deletion always occur first in the context of long vowels. Nowhere is VN >  $\tilde{V}$ N and subsequent  $\tilde{V}$ N >  $\tilde{V}$  reported in the absence of V:N >  $\tilde{V}$ :N and  $\tilde{V}$ :N >  $\tilde{V}$ :. Even spontaneous nasalization appears to be conditioned by vowel length. As reported earlier, only long \*/a:/ spontaneously nasalizes in Eastern Algonquian languages. Reflexes of its short counterpart \*/a/ are still oral. Similar is reported for Indo-Aryan languages.

Given the cross-linguistic evidence in favour of preferential long vowel nasalization we are able, like Hombert (1987), to formulate a universal parameter of sound change, the so-called Vowel Length Parameter:

#### (II) Vowel Length Parameter (VLP)

V:N >> VN

### **X.6 A New Hypothesis: Two Universals**

The experimental perceptual evidence suggests not one, but two competing patterns of interaction between vowel height and nasalization (and subsequent N-deletion): preferential high vowel nasalization v. preferential low vowel nasalization. Closer inspection of the available evidence points to two independent universals - only one of which is, however, directly height-related. High vowels are preferentially nasalized because, all other things being equal, low levels of acoustic perturbation favour the perception of nasalization on these vowels. On the other hand, increased vowel duration increases the perception of vowel nasalization, independently of and at all levels of nasal

coupling. It is generally accepted that intrinsic levels of vowel duration correlate in an inverse fashion with vowel height across languages: the lower the vowel, the greater its intrinsic duration (Lehiste, 1970, Laver, 1994 for references and details). For this reason, low vowel nasalization will be - indirectly - favoured.

How precisely do the two universals, governed by high vowels and duration respectively, interact? Our initial hypothesis is that duration may predominate - a consequence of the high perceptual sensitivity to duration effects, as well as consistent cross-linguistic vowel length patterning reported above. In any language the longest vowels (in terms of phonetic duration as well as its phonological derivative, length) will be preferentially nasalized. If correct, this hypothesis can be viewed as favouring low over high vowel nasalization - given the reported intrinsic duration differences. The smaller intrinsic duration of higher vowels will reduce the perceptibility of contextual nasalization, and therefore disfavour high vowel nasalization.

A very clear example of the influence of intrinsic duration on the spread of distinctive nasalization phenomena can be found in developments in Northern Italian dialects studied in some detail by Hajek (1992, 1997). In these dialects, the Latin vowel system developed into an intermediate four-height system contrasting in length, i.e. \*/i, e, ε, a, ɔ, o, u, i:, e:, ε:, a:, ɔ:, o:, u:/. In all but one of the nine dialects, there is evidence of phonologized nasalization (and often of subsequent N-deletion) in stressed syllables. The phenomena, where found, always occur preferentially in the context of historically long vowels, as can be seen from the data in (III). All historically long vowels are similarly affected, regardless of height and without exception. Nasalization of historically short vowels, on the other hand, is much less widespread, and is always restricted to dialects in which historically short vowels have already been lengthened. In some dialects, lengthening has not yet been followed by nasalization, e.g. Bolognese. Significantly, there is no evidence of short nasal vowels in stressed syllables in any context in any dialect. A very strong constraint operates, therefore, in which only vowels which are phonologically long may be subject to secondary nasalization.

(III) Latin	/pa:ne/ ‘bread’	/annu/ ‘year’
Proto-Northern Italian (PNI)	*/pa:n/	*/an/
Tavetsch	[paw̃n]	[ɔ̃n]
Milan	[pã:]	[an]
Cairo	[pãŋ] (< [pã <sup>ũ</sup> ])	[an]
Bergamo	[pa(:)] (< [pã:])	[a(:)n]
Bologna	[pæŋ] (< [pæ <sup>ũ</sup> ])	[a:n]
Rimini 1918	[pɛ:n]/[pɛ̃:n]	[a:n]
Rimini 1991	[pɛ̃:n]	[ã:n]
Lugo	[pɛ̃:]	[a:n] (no nasalization)
Imola	[pɛ̃:]	[ɛ̃:n]
Ravenna	[pã:]	[ã:n]

Lengthening of short vowels in Northern Italian is strictly height governed, and reflects general observations about the intrinsic duration of vowels. In any context where lengthening occurs, low \*/a/ is everywhere the first to be affected. In more innovative dialects such as Imola, nasalization may follow. Less frequent is secondary lengthening of short \*/e, ɔ/. Nowhere are high-mid \*/e, o/ and high \*/i, u/ lengthened.

In an earlier section we cited Northern Italian as an example of preferential low vowel nasalization. We see now that vowel height conditions nasalization only indirectly: the spread of nasalization phenomena is entirely dependent on a gradual process of height conditioned vowel lengthening.

Two important caveats need to be placed on the intrinsic vowel duration hypothesis in favour of preferential low vowel nasalization. First, Whalen & Beddor (1989) claim that the intrinsic duration differences between low and high vowels are not sufficient to trigger

preferential nasalization of the former. They suggest that, according to the results of their perception experiments, the average 60 ms. difference between [a] and [i] in English would not be enough to have more than a small effect on perceptibility of nasality in favour of [a]. They take a very conservative position and conclude that '[a]pparently, only the large differences of duration due to distinctive vowel length are sufficient to contribute to distinctive nasalization.' Second, the correlation between vowel height and duration in favour of low vowels is cross-linguistically widespread but not universal. It is reported not to hold in some languages, e.g. Farsi, Norwegian (Cochrane, 1970). In Herve French, measurements suggest that /u:/ is no shorter than /a:/, whilst /i:/ is 50% longer (126 ms.) than its low counterpart (Detry, 1985). We consider then these two caveats to work in favour of high vowel nasalization. Only in languages where low vowels are substantially longer than their higher counterparts, as appears to have been the case in Northern Italy, might we then expect nasalization of the former to be favoured.<sup>3</sup>

### Conclusions

The claim that distinctive nasalization will always develop preferentially in the context of low vowels is not confirmed. Despite the range of evidence usually cited in support of such a claim, close investigation finds much of the evidence to be problematic. The philological evidence of developments in Old French is seen to be strongly unreliable. The cross-linguistic data is conflicting: two patterns are uncovered whereby high vowels in some languages and low vowels in others are preferentially nasalized. Although it has sometimes been claimed that relative velic opening, predictably conditioned by vowel height, is responsible for a perceived universal preference for low vowel nasalization, velic opening is found not to correlate with vowel height across languages and speakers in the strictly universal fashion sometimes claimed. The available perceptual evidence of vowel height conditioning is consistent with the two contradictory cross-linguistic patterns of development: some studies find high vowels to be perceptually more nasal, whilst others report low vowels to be more nasal. This perceptual split can be accounted for by different duration patterns. Where duration was not controlled for, perception on low vowels was favoured - because across languages these are generally the longest. Other perceptual studies also confirm the link between levels of perceived nasality and vowel duration: as the latter increases, so does the former. Available cross-linguistic developments provides further support by showing that long vowels will always be preferentially nasalized. Overall indications are that perceptual factors are predominant over articulatory ones in the phonologization and spread of nasalization-related phenomena.

We conclude, on the basis of the cross-linguistic and perceptual data, that there appear to be two competing universal tendencies, if not universals: one is of preferential nasalization of high vowels, and the other is of preferential nasalization of vowels with greatest duration (generally accepted to be low vowels). How precisely the two tendencies interact, so that only one or the other seems evident in most languages, is not entirely clear at the moment. But developments in Northern Italian allow us to see how the development and spread of nasalization phenomena, seemingly according to vowel height, interacts with the gradual and ordered spread of a phonetically conditioned phonologization of vowel lengthening - a process which is generally predicted to favour the nasalization of low vowels.

Finally, we observe only in passing that the results of this study appear to be consistent with recent developments in phonological theory. In Optimality Theory phonological output is governed by the language-specific ranking of competing constraints (ultimately considered by many to have a phonetic basis). Constraints are no longer unique, 'hard', and therefore exceptionless across all languages. They are now viewed as competing, variably ranked and hence 'soft', allowing for a permitted range of variation across languages - of the type noted here for instance: low vowels preferentially nasalized in some languages, and high vowels in others.

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<sup>1</sup> Some readers have suggested that in a sample of more than 1200 dialects, the existence of only a handful of counter-examples provides overwhelming support nevertheless for the VHP. But as already noted in the main text, the Chinese sample seems affected by bias. For instance, our earlier reanalysis of developments in 129 Hebei dialects substantially reduces the number of dialects previously thought to demonstrate preferential low vowel nasalization. Moreover, the fact that we can only add another 3 dialects to the list with preferential high vowel nasalization merely reflects the very limited amount of dialect-specific data available in Chen (1975). Reassessment of all Chinese sample data is advisable before any claim, based on such data, in favour of the VHP can be properly accepted.

<sup>2</sup> There is some debate as to whether moderate contextual nasalization in low vowels is perceived by listeners as an enhancement of lowness rather than of nasalization *per se* (see Kingston 1991 for details).

<sup>3</sup> As one anonymous reviewer points out, this hypothesis could be tested by looking at vowel duration in those languages noted in sections X.3.2 and X.4.2.1 where high vowels are preferentially nasalized in some way. Unfortunately, there is no phonetic data with respect to vowel duration for any of these languages currently available.



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