More evidence for the perceptual basis of sound change? Suprasegmental effects in the development of distinctive nasalisation:

John Hajek[1] and Ian Watson[2]

[1] School of Languages, University of Melbourne

[2] Christ Church, Oxford and Oxford University Phonetics Laboratory

ABSTRACT

Cross-linguistic studies of the development of distinctive nasalization show evidence of significant suprasegmental conditioning. Amongst conditioning factors uncovered so far are vowel length and stress. Across languages it is reported that in the related contexts /V:N/ and /VN/, identical except for vowel length, phonologization of nasalization and N-deletion always occur preferentially in the context of long vowels. There is also cross-linguistic evidence of stress-conditioning of distinctive nasalization: nasalization and N-deletion appear to occur preferentially in stressed syllables. In this study, we discuss the results of an experiment designed to measure the possible effects of vowel duration and prominence on the perception of vowel nasalization. Both are seen to have an effect, although in different ways. Results presented here also lend support to the hypothesis that some sound changes, such as those involved in distinctive nasalization, may have a primarily perceptual basis.

1. INTRODUCTION

In a recent detailed cross-linguistic survey of the development of distinctive nasalization (e.g. an > ãn > ã), Hajek [1] finds extensive evidence of suprasegmental conditioning. Amongst factors examined, very prominent is the predictable effect of vowel length on the spread of both vowel nasalization and of N-deletion. In all languages examined with a vowel length contrast, the historical sequence /V:N/ is always the preferred locus for any or all parts of the process of distinctive nasalization. Where nasalization and/or N-deletion is reported in the context of short vowel + N, then the same is also found in the context of long vowels. The reverse case of short nasal vowel (with or without N-deletion), but long vowel remaining oral before N Is not found anywhere. In some Northern Italian dialects for instance, we find examples such as:

(1) [ve) :na] < /ve:na/ but [pena] < /pena/
[kE) :] < /ka:n/ but [a:n] < /an/

In Kire, a non-Austronesian language spoken in Papua New Guinea, both short and long vowels are nasalized before tautosyllabic N, e.g. [gu) mgi] 'men' and [nte) :n] 'fish sp. (sg.)'. However, only long vowels are nasal before heterosyllabic N, e.g. [nte) :ni)] 'fish sp. (pl.)'. Short nasal vowels are not permitted in the same context, e.g. [gumã] 'man'.
The degree of patterning uncovered by Hajek [1] is so regular that the so-called Vowel Length Parameter (VLP) can be formulated: it states that over time distinctive nasalization will occur preferentially in the context of long vowels before spreading to short vowels:

(2) V:N VN (VLP)
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In some areas, such as Northern Italian, operation of the VLP is so constrained that short vowels must be lengthened before they can undergo nasalization.

The presence or absence of stress is also reported by Hajek [1] and by Schourup [4], to have a predictable effect on the development of distinctive nasalization: the phenomenon is always found to occur preferentially in stressed position, as the following examples taken from another Northern Italian dialect demonstrate: ['kã:] < /'ka:n/ 'dog', ['ã:n] < /'an/ 'year', but ['stevan] < /'stefan/ 'Stephen'.

Hajek & Maeda [2] have proposed that given (a) the evident suprasegmental conditioning in the development of distinctive nasalization, as seen in the available cross-linguistic evidence, and (b) available experimental data, the sound changes in question are more perceptually motivated than articulatory in nature. Such a hypothesis is of course consistent with Ohala's [3] listener-oriented/perceptual model of sound change. The best available experimental evidence in support of Hajek & Maeda [2] comes from a study by Whalen & Beddor [5]. Using synthetic tokens, they found that listeners' perception of vowel nasalization rose monotonically as vowel duration was increased - regardless of vowel height and quality. Whalen & Beddor [5] were not able to fully explain their results, but suggest that some kind of summation effect in the case of vowel duration appeared to enhance perception of nasality. In a series of separate experiments, they did not find other factors, such as amplitude, or F0 to have a similar effect.

2. PERCEPTUAL EXPERIMENT

The historical data thus suggest that both vowel length and prominence - whether a syllable is stressed or unstressed - affect the perception of vowel nasality. In the perceptual experiment, we sought (i) to confirm Whalen & Beddor's [5] finding that long vowels favour nasal percepts; (ii) to examine the role of stress; and (iii) to investigate the interaction, if any, between stress, vowel length and velopharyngeal opening (VPO).

2.1 Stimuli

A series of twelve disyllabic synthetic stimuli was created using the HLSYN pseudo-articulatory synthesizer. This synthesizer drives an implementation of the KLSYN formant synthesizer using 10 articulatory variables specified by the experimenter, including degree of velopharyngeal port opening (VPO), specified in mm^2. The stimuli were designed to vary from [asa] to [ãsa] in three steps, specified by setting VPO for the first vowel to 0, 16.8 and 36 mm^2; these correspond to three of the levels used by Whalen and Beddor [5]. The number of VPO levels was reduced relative to that study, due to the larger number of other variables being tested here. To test the effect of vowel length, for each degree of VPO, two length settings were used, 250 ms and 150 ms (again reduced, relative to Whalen and Beddor). To test the effect of prominence, the relation between the vowels in the first and second syllables was varied. In the stressed condition, the first (target) vowel was 100 ms. longer than the second vowel. The former also had a higher intensity than the second (the control parameter for subglottal pressure was set to 8.5 cm H_2O for the first and 6 cm H_2O for the second), and was marked by a major F0 fall of 55 Hz (from 145 to 90 Hz), while the second vowel had level pitch. In the unstressed condition, the second vowel was correspondingly louder, longer and more pitch prominent.

This gives a total of 3 (VPO settings) x 2 (length settings) x 2 (prominence conditions), i.e. 12 stimuli. These were recorded six times in pseudo-random order onto a tape, with an inter-stimulus interval of 3 seconds..

2.2 Subjects and procedure

The subjects were ten native speakers of British English, all students at Oxford University. None was a native speaker of any other language. One was studying German, otherwise, none had studied any language beyond secondary school level. They were asked to respond to each stimulus by marking on a pre-prepared sheet how nasalised they considered the first vowel to be, on a scale 1 (least nasal) - 5 (most nasal). Subjects were run individually, the experiment being preceded in each case by a short practice session. The first twelve responses in the experiment itself were discarded for each subject, leaving five responses to each stimulus. These were then input to a repeated measures 3-way ANOVA, with dependent variable nasality judgement, and factors VPO, vowel length, subject and prominence of first vowel. Planned contrasts were made between the three VPO conditions, the prominence*length and the prominence*VPO interactions.

2.3 Results

Results are shown in Figure 1. Nasality judgements increased with VPO, and with vowel length. The effect of prominence was more complex. When there is some degree of VPO, vowels were rated more nasal in stressed than in unstressed syllables. When VPO was zero, the reverse was true.

The ANOVA showed that the following main effects were significant (p values are corrected using the Huynh-Feldt epsilon criteria): VPO [2,8] $F = 213.2$, $p < .0001$; length [1,4] $F = 26.1$, $p < .007$; subject [9,36] $F = 8.1$, $p < .001$. Prominence ([1,4], $F = .159$, $p > .7$) was not significant as a main effect. However, the following interactions were significant: prominence*velic opening [2,8] $F = 23.0$, $p < .002$; prominence*subject [9,36] $F = 3.2$, $p < .015$; VPO*subject [18, 72] $F = 6.3$, $p < .0001$. Thus, prominence does play a secondary role in conditioning responses to the VPO factor. The role of length is confirmed, as found by Whalen & Beddor. However, the prominence*length interaction was not significant ([1,4], $F = .441$, $p = .543$).

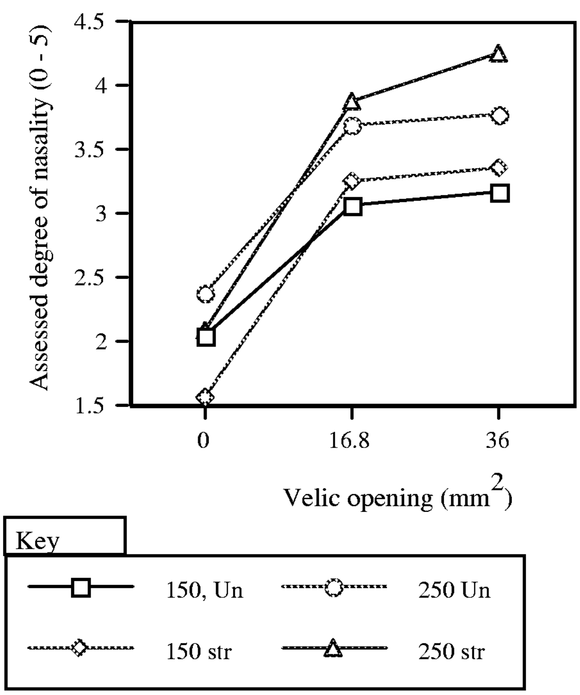

Figure 1. Nasality Judgements Figures in key refer to length of first vowel in ms. Un = unstressed, str = stressed.

The planned comparisons showed that the VPO opening of 0 mm^2 was significantly different from both the 16.8 mm^2 and the 36 mm^2 openings (for both, $p < .001$) but that the 16.8 mm^2 and the 36 mm^2 openings were not significantly different ($p > .1$). For the prominence*velic opening comparisons, the comparisons between stressed and unstressed were highly significant for VPO = 0 mm^2 (df = 1, F = 23.5,$p < .0025$) and for VPO = 36 mm^2 (df = 1, F = 17.7, $p < .01$), but only marginally so for VPO = 16.8 mm^2 (df =1, F = 5.87, p = .0505 after H-F correction).

3. DISCUSSION

As expected, the role of the length parameter, predicted from historical studies and already shown to be salient experimentally by Whalen and Beddor [5] is confirmed here. A role is also confirmed for stress conditioning. This latter effect appears initially to be considerably less powerful than that of the length parameter; the analysis of variance shows it only to be effective in its interaction with VPO, rather than as a main effect. However, care is appropriate in interpreting this finding. The planned comparisons showed that there was a highly significant difference between the stressed and unstressed conditions for both the lowest and highest levels of VPO, and a marginally significant difference for the middle level. The reason for the non-significance of prominence as a main effect is thus not due to its lack of salience, but rather due to the fact that, between the lowest VPO condition and the others, the effect goes in the opposite direction. As Fig. 1 confirms, nasality judgements for VPO = 0 mm^2 were higher in the unstressed condition. For the other degrees of VPO, they were higher in the stressed condition.

The reason for this is unclear. As Whalen and Beddor [5] note, it is quite usual for subjects to judge synthetic vowels (especially open vowels) as having some nasality even when VPO is set to zero. However, this does not explain why stress should reduce this tendency. The finding is all the more surprising because in this experiment, the vowels were not heard in isolation, but always adjacent to another vowel, which in the relevant (VPO = 0 mm^2) condition was identical except for its prominence. In other words, subjects had available a comparison which should have reinforced the non-nasalised quality of the target vowel. In fact, the difference in prominence caused the vowels to be judged as different.

A possible explanation might be an Ohala-like filtering effect on the part of the subjects. At low levels of VPO listeners might be readier to discount minor signs of nasality, such as occur with synthetic vowels, to a greater extent in stressed syllables than unstressed ones. However, above a certain threshold of VPO, indicating that the speaker has deliberately nasalised the vowel, nasality on stressed syllables becomes more salient. To test this explanation, further experiments with more different degrees of VPO would be necessary.

A second surprising aspect of our results is the lack of significant difference between the medium and large levels of VPO. This suggests that, in our stimuli, a VPO of 16.8 mm^2 was sufficient to give a strong nasal percept, the increase to 36 mm^2 having no significant effect. This result differs from that of Whalen & Beddor [5]. This difference between the two studies may again be attributable to the use, here of disyllables, the second of which was never nasalised. This made available to our subjects a comparison which those of Whalen & Beddor [5] did not have. A relatively low level of VPO may seem much more salient when directly comparable to a total absence thereof than it does in isolation. Again, further experiments are needed to address this possibility, using either monosyllables, or disyllables in which both vowels are nasalised.

4. CONCLUSION

Overall, our results appear to lend weight to the hypothesis that the development of distinctive nasalization is sensitive to suprasegmental conditioning, and has a strongly perceptual basis. Listeners' ability to perceive nasality is affected by manipulation of suprasegmental cues. The role of the vowel length parameter in the perception of vowel nasality has been experimentally confirmed, and that of prominence also established. The latter, however, interacts with VPO in a complex manner, which calls for further experimentation. Future studies could also investigate the interaction between prominence and the position of the nasal in the word, and the effect of different types of foot structure on the perception of nasality in vowels.

5. REFERENCES

1. Hajek, John, *Universals of Sound Change in Nasalization*. Oxford: Blackwell, 1997.

2. Hajek, J. & S. Maeda, 'Investigating Universals of Sound Change: the effect of vowel height and duration on the development of distinctive nasalization'. In J. Pierrehumbert & M. Broe (eds.) *Papers in Laboratory Phonology V*, Cambridge: Cambridge University Press (in press).

3. Ohala, J. 'The phonetics of sound change'. In Charles Jones (ed.) *Historical Linguistics, Problems and Perspectives*, London: Longman, 237-278, 1993.

4. Schourup, L. C. 'A cross-language study of vowel nasalization', *Ohio State University Working Papers in Linguistics* 15: 190-221, 1973.
5. Whalen, D. & P. Beddor, 'Connections between nasality and vowel duration and height: Elucidation of the Eastern Algonquian intrusive nasal'. *Language* 65: 457- 486, 1989.