ORAL-NASAL VOWEL CONTRASTS: NEW PERSPECTIVES ON A DEBATED QUESTION

Kofi Adu Manyah

Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
adukofi20022003@yahoo.com

ABSTRACT

This study deals with data about the acoustic properties of nasal vowels of the Twi language, spoken in Ghana, compared to the oral counterparts. Evidence from our data shows a general tendency whereby F2 and F3 of the nasal vowels are lower than the oral counterparts in both the short and long contexts. Acoustic data also reveal that nasal-oral contrast depends on the vowel type. Nasal vowels have higher durational values than oral vowels in the short and long phonological categories.

Keywords: vowels, oral, nasal, formants, duration

1. INTRODUCTION

The language under study has nine oral vowels: \i\, \ɪ\, \e\, \ɛ\, \a\, \ɔ\, \o\, \ʊ\, \u\ and five nasal vowels. They are the contrasting counterparts of the two high front oral vowels, \i\ and \ɪ\ the two high back vowels, \ʊ\ and \u\, and the low vowel \a\. Nasals are used for lexical distinctions and they contrast with the oral vowels after voiceless consonants. In both the oral and written contexts Twi also has two contrasting lengths in words. Quantity is used for lexical and grammatical distinctions where the vowel is either short or long.

The primary aim of this study is to undertake acoustic analyses and to compare the production of oral and nasal vowels and present the acoustic results in both the short and long categories. First, durational analyses of oral and nasal short/long vowels are made. Second, formant structure investigations are undertaken for the two phonological classes.

Building in part on previous research, this investigation differs in one important respect. Nasal study or nasal/oral comparison that takes into account both short and long vowels, i.e. phonemic quantity contrasts, has received very little or no attention in the literature. In their acoustic and/or aerodynamic studies [4, 6, 11], in acoustic, articulatory, perception contributions [2, 3, 6, 7, 10, 16, 17, 19, 20], none of these sources refer to phonemic quantity contrasts. In other words, unlike most descriptive or oral/nasal comparative methods proposed in the literature, this study analyses both short and long vowels of the two phonological classes. Nasals in Twi have also remained under-studied, so this investigation is a contribution to research on oral/nasal comparison that has been extensively studied in a good amount of languages.

Previous studies on nasals [9, 10, 16] suggest that resonant frequencies are lower than the oral counterparts. There is also more damping resulting in lower formant intensity especially in the range of the second formant F2 related to changes in spectral balance due to the loss of energy at higher frequencies. The vocal tract is also shorter for nasal vowels. Nasal vowels are more rounded, more open and more back than the oral counterparts. The current study will examine segmental durations and formants of the two phonological classes.

2. METHOD

Two male adult native speakers with no speech or hearing impairment were chosen for this experiment. They produced Twi minimal pairs, of the two phonological classes, embedded in a carrier sentence 'Kã sɛ__Kofi' meaning 'Say__ Kofi'. The corpus was made up of oral/nasal contrasts for the short and long categories in a C_1VC_2 context where C_1 is /p/, /t/, /k/, V is the short and long oral or nasal vowel, and C_2 is /k/ of the carrier phrase. Acoustic recordings were done with a Sennheisser E 845 S directional microphone connected to a Marantz Professional Solid State Recorder PMD660. The recordings were done at a self-selected speaking rate in an anechoic room. The randomised list of utterances was produced at least 10 times by each speaker.

First, by means of a Praat sound editor, the acoustic analysis was performed. Measurements of duration were taken for the target vowel and the post-vocalic consonant /k/, thus obtaining 3 different durations: the target vowel, the post-vocalic consonant and the syllable V+C durations. Second, to control vowel quality for the 2 phonological categories, formant values (F1, F2, F3, F4) were extracted at three equidistant points within each of the oral and nasal vowels: at 25%, 50% and 75% of the duration of the vowel. The data were then averaged over the ten repetitions of each (short/long)

oral and nasal vowel. The extraction of formant values was done manually to achieve high accuracy. Statistical analyses (ANOVAs) were carried out on all measures obtained from the speakers ($p \leq 0.01$). Here are examples of monosyllabic words from the corpus:

/ka/	'bite'	vs.	/kã/	'say', 'drive'
/kaa/	'bit'	vs.	/kãã/	'said', 'drove'
/tʊ/	'throw', 'buttocks'	vs.	/tũ/	'roast', 'bake'
/tʊʊ/	'threw'	vs.	/tũũ/	'roasted', 'baked'

3. RESULTS AND DISCUSSION

3.1. Durational data analyses

Vowel data comparison of absolute values in the oral and nasal groups reveals that nasal vowels are systematically longer than the oral counterparts for both short and long vowels, for the two subjects. This is in agreement with previous findings on vowel durations [5, 12, 14, 15, 23]. As depicted in figs 1 and 2, short /i/ measures 88 ms and long /i/ 252 ms with very low standard deviations of 11 ms and 29 ms, whereas the nasal counterpart measures 113 ms and 279 ms (standard deviations of 14 ms and 23 ms) for the short and long respectively for Speaker 1. The corresponding values for the second speaker are 58 ms and 124 ms (standard deviations: 10 ms and 28 ms) for oral /i/ and 87 ms and 195 ms, with low standard deviations of 09 ms and 25 ms for nasal /ĩ/.
Relative values show that in the VC domain phonologically short vowels are followed by phonetically long consonants. As shown in a previous study involving same speakers and data [1], differences in consonant duration between short and long oral vowels are statistically significant ($p<0.001$). With regards to phonologically long oral vowels, this can be observed: the post-vocalic consonant is slightly longer than, equally long or slightly shorter than the vowel. Thus, there seems to be no compensatory relation between the long vowel and the consonant in the VC domain. However, this is not the case with the nasal vowels since there is a compensatory relation between phonologically long vowels and post-vocalic consonants: phonologically long vowels are systematically followed by phonetically short consonants in the VC domain (see fig. 1 & 2).

In the VC domain, phonologically short vowels are followed by phonetically long consonants in both the oral and nasal categories. Post-vocalic consonant duration differences seem to reinforce vowel quantity contrasts in the language under study. The nasal category of vowels registers higher ratios than the oral for both speakers.

Figure 1: This figure shows average oral vowel, nasal vowel and post-vocalic consonant durations and standard deviations for the first speaker (ms).

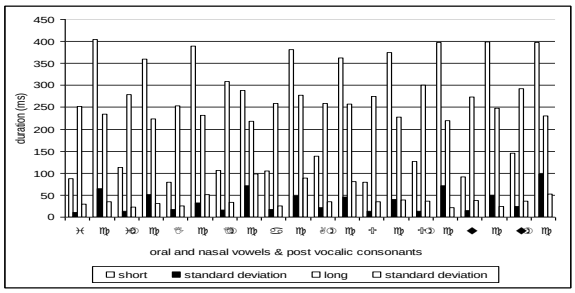
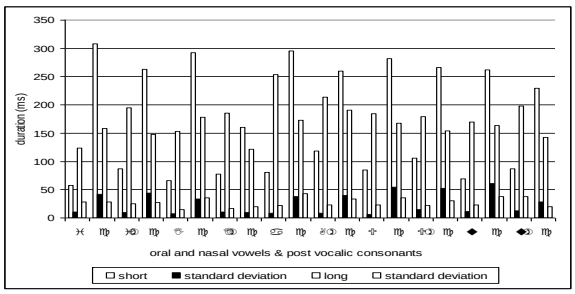


Figure 2: This figure shows average oral vowel, nasal vowel and post-vocalic consonant durations and standard deviations for the second speaker (ms).



Differences in consonant duration between long and short vowels have also been attested for in the dialects of Modern Swedish [21]. The authors further posit that there is a complementarity pattern whereby the long V+C (V:C) sequences have the tendency of possessing almost the same duration as the short V+C (VC:) sequences. According to their findings the V:C types are in general slightly shorter in total duration than the V:C sequences. In the present study, the phenomenon seems to be observed for all oral and nasal vowels produced by the first Twi speaker (67% of all cases), where the VC: sequences are in general slightly shorter than the V:C counterparts. In the case of the second speaker, the complementarity pattern seems to apply partially, without reference to the vowel duration. Indeed, the tendency is verified in only 39% of the cases in both oral and nasal contexts. Comparing the data of only the nasal vowels, it can be observed that this trend applies to the two front vowels /ĩ/, /ɪ̃/ and the open vowel /ã/ but not to the 2 back vowels /ũ/ and /ʊ̃/for speaker 1. (See fig. 1 & 2 again). Thus, the observation on the pattern is in accordance with results obtained for Bolognese where it is shown that the phenomenon is only partially applicable [13]. The findings of this study on phonological durational contrasts and the contribution of the post-vocalic consonant to distinguish the two classes have already been documented on studies in Thai [18] and Bolognese [13]. In the group of long vowels, figs 1

and 2 show that post-vocalic consonant durational values are close to vowel durations. The difference between the two values are not statistically significant *(p=ns).*

3.2. Spectral data analyses

As illustrated in figs 3 and 4, the comparison of formant values of the oral and nasal vowels shows that F2 of the nasal vowels are lower than the oral counterparts, particularly for the high front short vowels /i/ and /ɪ/ (1651 Hz for the nasals and 2117 Hz for the oral counterparts for /i/ and 2061 Hz and 2066 Hz for /ɪ/). The corresponding F2 values for the long vowels /i/ are 1626 Hz for the nasal and 2176 Hz for the oral counterpart. The F2 values for /ɪ/ are 1966 Hz and 2120 Hz for the nasal and oral categories respectively. The results in the present study seem similar to the F2 results obtained for French nasal vowels [10]. However, this does not seem to apply to the low vowel /a/ and the two high back vowels /ʊ/ and /u/. In fact, for the high back vowel /u/, it is rather F2 of the oral vowel which is lower than the nasal counterpart: oral (1236 Hz) and nasal (1519 Hz) for the short vowels, and oral (1079 Hz) and nasal (1432 Hz) for the long vowels (see fig. 3 & 4 again). The comparison also reveals that, in the oral and nasal categories, the formants F1, F2, F3 and F4 of the long and short vowels do not exhibit any significant differences *(p=ns).*

In order to take a closer look at the three extreme vowels of the vowel triangle /i, a, u/, oral and nasal curves were plotted on the same graph (fig. 5) allowing comparison of analytical data. We observe the following for the long vowels: for the high back vowel /u/ there are very small differences in the formant structure of the oral- nasal contrast which are not statistically significant *(p=ns).* For the low vowel \a\ the relatively weak difference in the formant structure is located at the first formant: F2, F3, F4 are almost identical. On one hand, a comparison of F1 and F2 in the oral and nasal categories shows that the front vowels are characterized by wider or distant F1 and F2 whereas the back vowels are characterized by narrower or close F1 and F2. This is consistent with previous investigations on nasals where it is shown that for a back vowel F2 is low and close to F1, whereas for a front vowel F2 is high and far from F1 [17, 22]. On the other hand, an F2 and F3 comparison indicates a closer characteristic for front vowels and wider or distant characteristic for back vowels. In other words, F2 is close to F3 for front vowels /i/ and /ɪ/ but distant for the back vowels /ʊ/ and /u/. The same characteristics about front and back vowels are found in an F3 and F4 comparison (see fig. 3 & 4 again).

Figure 3: This figure shows formant values for short oral and nasal vowels /i ɪ a ʊ u/ for Speaker 2.

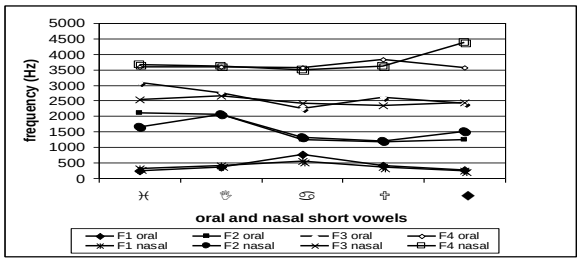


Figure 4: This figure shows formant values for long oral and nasal vowels /iː ɪː aː ʊː uː/ for Speaker 2.

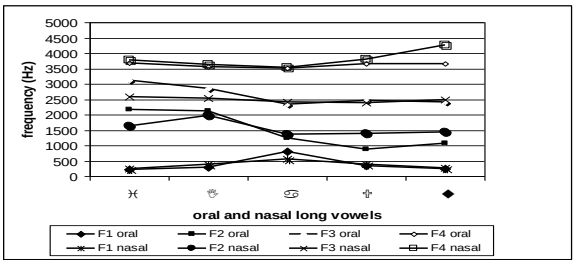
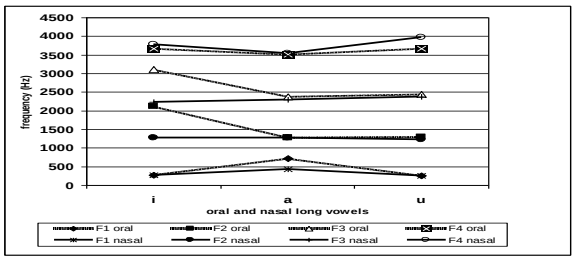


Figure 5: Oral and nasal long vowels: Comparison of formant values for /i, a, u/ for the second speaker.



It seems from the foregoing that quality differences between oral and nasal vowels operate more within the high front vowel /i/ than the high back vowel /u/ and the low vowel /a/. Data also suggest that, for the high front vowel, the quality differences operate at the second and third formants rather than the first formant, unlike the low open vowel /a/. For the low vowel, the relative difference in quality is found at the first formant as illustrated in figure 5 where, on one hand, nasalization causes F1 to lower. On the other hand, nasalization seems to cause F2 to raise in the case of the high back vowel /u/ but not in that of the high front vowel /i/ as depicted in figs 3 and 4.

Assuming also that vowel dispersion refers to how dispersed the vowels are in phonological space, the scatter plots (F1 on the ordinate and F2 on the abscissa) prepared to represent data, clearly illustrate that the oral vowels /i, a, u/ are less widely dispersed in phonological space than the nasal counterparts (fig. 6 & 7).

Figure 6: Dispersion of long nasal vowels /ĩ, ã, ũ/ for Speaker 2 (Hz).

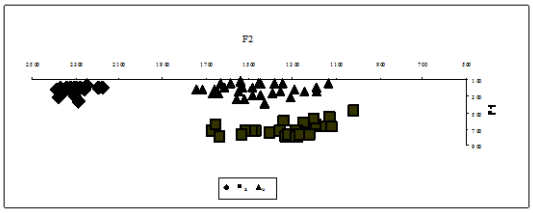
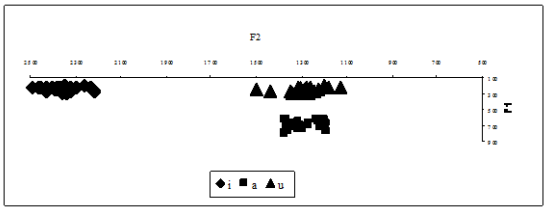


Figure 7: Dispersion of long oral vowels /i, a, u/ for Speaker 2 (Hz)



4. CONCLUSION

This study has shown, on the basis of acoustic data, that nasal vowels are longer than their oral counterparts in both the short and long contexts. Thus the current study supports durational analyses of orals and nasals reported in previous studies [5, 12, 14, 15, 23]. Whereas phonologically long nasal vowels are systematically followed by phonetically short consonants in the VC domain, phonologically long oral vowels and post-vocalic consonants show no coherent compensatory behaviour. Phonologically short vowels are followed by phonetically long consonants in the oral and nasal contexts. Acoustic evidence also shows that the F2 values are generally lower for the nasal vowels than the oral vowels. This confirms the tendency which is characteristic of nasal vowels. However, the findings of this study suggest that this rule does not apply to the vowel /u/. F2 values are rather lower for the oral vowels than the nasal vowels in both the short and long categories. I have also shown that even though the two phonological classes exhibit slight qualitative differences which are not statistically significant, the front vowel /i/ shows a relatively significant difference at the second and third formants compared to /u/ and /a/, suggesting that the degree of nasality, and for that matter nasal-oral contrast, depends on the vowel type. Acoustic investigations further reveal that nasal vowels are more widely dispersed than the oral vowels in phonological space.

5. REFERENCES

[1] Adu Manyah, K. 2003. Vowel quantity contrasts in Twi, *Proc. 15th ICPhS* Barcelona, 3185-3188.

[2] Amelot, A., Basset, P., Maeda, S., Honda, K., Crevier-Buchman, L. 2008. Etude simultanée des mouvements du voile du palais et de l'ouverture du port vélopharyngé. *XXVII è JEP* Avignon, 65-68.

[3] Beddor, P.S. 2007. Nasals and nasalization: The relation between segmental and coarticulatory timing. *16th ICPhS* Saarbrücken, 249-254.

[4] Clairet, S. 2008. Une étude aérodynamique de la nasalité vocalique en français méridional. *XXVII è JEP* Avignon, 297-300.

[5] Delattre, P., Mannot, M. 2009. The role of duration in the identification of French nasal vowels. *IRAL* 6, Issue 1-4, 267-288.

[6] Delvaux, V. 2006. Production des voyelles nasales en français québécois. *XXVI è JEP* Dinard, 383-386.

[7] Delvaux, V. 2009. Perception du contraste de nasalité vocalique en français. *Journal of French Language Studies* 19(1), 25-59.

[8] Delvaux, V., Demolin, D., Harmegnies, B., Soquet, A. 2008. The aerodynamics of nasalization in French. *Journal of Phonetics* 36, 578-606.

[9] Delvaux, V., Metens, T., Soquet, A. 2002. French Nasal Vowels: acoustic and articulatory Properties. *Proc. 7th ICSLP* Denver 1, 53-56.

[10] Delvaux, V., Metens, T., Soquet, A. 2002. Propriétés acoustiques et articulatoires des voyelles nasales du français. *XXIV è JEP.* Nancy, 348-352.

[11] D'Imperio, M., Raposo de Medeiros, B., Espesser, R. 2008. La voyelle nasale en Portugais Brésilien et son appendice nasal: Étude acoustique et aérodynamique. *XXVII è JEP* Avignon, 285-288.

[12] Duez, D. 2006. Consonant and vowel duration in Parkinsonian French Speech. *Speech Prosody* Dresden.

[13] Hajek, J. 1994. Phonological length and phonetic duration in Bolognese: Are they related? *Proc. 5th Australian Int. Conference on Speech Science and Technology* 2, 662-667.

[14] Jha, K.S. 1985. The nasal vowels in Maithili: An acoustic study. *Contributions to Nepalese Studies* CNAS Tribhuvan University, 13(1), 19-32.

[15] Lovatto, L., Amelot, A., Crevier-Buchman, L., Basset, P., Vaissière, J. 2007. A fiberscopic analysis of nasal vowels in Brazilian Portuguese. *16th ICPhS.* Saarbrucken, 549-552

[16] Maeda, S. 1993. Acoustics of vowel nasalization and articulatory shifts in French nasal vowels. In Huffmann, M. K., Krakow, R.A. (eds.), *Phonetics & Phonology, Vol. 5. Nasals, Nasalization, and the Velum.* Academic Press, 147-167.

[17] Menard, L., Schwartz, J-L., Boe, L-J., Aubin, J. 2007. Articulatory-acoustic relationships during vocal tract growth for French vowels: Analysis of real data and simulations with an articulatory model. *Journal of Phonetics* 35, 1-19.

[18] Mixdorff, H., Lukaneeyanawin, S., Fujisaki, H., Charnvivit, P. 2002. Perception of tone and vowel quantity in Thai. *Proc. ICSLP*, 753-756.

[19] Montagu, J. 2004. Les sons sous-jacents aux voyelles nasales en français parisien: Indices perceptifs des changements. *XXV è JEP* Fez. 385-388.

[20] Montagu, J. 2002. L'articulation labiale des voyelles nasales postérieures du français: Comparaison entre locuteurs français et anglo-américains. *XXIV è JEP* Nancy, 253-256.

[21] Schaeffling, F., Wretling, P. 2003. Towards a typology of phonological quantity in the dialects of Modern Swedish. *Proc. 15th ICPhS* Barcelona, 2697-2700.

[22] Stevens, K.N. 1985. Spectral prominences and phonetic distinctions in language. *Speech Communication* 4, 1-3, 137-144.

[23] Whalen, D.H., Beddor, P.S. 1989. Connections between nasality and vowel duration and height. Elucidation of the Eastern Algonquian intrusive nasal. *Language* 65, 457-486.