Nasal-Oral Contrast of Short and Long Vowels in Twi: An Acoustic Study

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1. Introduction

The language under study has nine oral vowels /i/, /ɪ/, /e/, /ɛ/, /a/, /ɔ/, /o/, /ʊ/, /u/ and five nasal vowels: /ĩ/, /ɪ̃/, /ɑ̃/, /ʊ̃/, /ũ/. The nasals are the contrasting counterparts of the two high front oral vowels, /i/ and /ɪ/, the two high back oral vowels, /ʊ/ and /u/, and the low vowel /a/. Nasal vowels are used for lexical distinctions and they contrast with the oral vowels after voiceless consonants (/t/, /k/, /f/, /s/ as can be seen in examples 1 to 9). As shown in the examples that follow, nasal vowels rarely occur before or after the semi-vowels /w/, /j/ and never after voiced consonants like /b/ and /d/, in their distribution, unless the vowel is followed by a nasal consonant:

(1) ti 'head' *vs.* tĩ 'scratch'

(2) to 'throw, buttocks' *vs.* tõ 'bake, roast'

(3) ka 'bite' *vs.* kã 'say'

(4) fa 'take' *vs.* fã 'half'

(5) fi 'go out' *vs.* fĩ 'dirt', 'dirty'

(6) se 'sharpen' *vs.* sẽ 'tooth'

(7) nsa 'hand' *vs.* nsã 'alcoholic drink'

(8) so 'on' *vs.* sõ 'be big'

(9) su 'character' *vs.* sũ 'cry'

In both the oral and written contexts the Twi language also has two contrasting lengths in words. Quantity is used for lexical and grammatical distinctions where the oral or nasal vowel is either short or long. Quantity contrasts affect the entire vocalic system of the language. Differences in quantity distinguish the present progressive, the present habitual, the present perfect, the simple future and the

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immediate future from the past forms of the verb. Lexical-grammatical distinctions (verb-noun, verb-adjective, verb-adverb, noun-adjective, noun-adverb and adjective-adverb) are also made through differences in vowel length. Some examples are given below:

(10) /akura/ 'mouse' *vs.* /akuraa/ 'village'

(11) /pɛ/ 'like, desire, same' *vs.* /pɛɛ/ 'liked, desired'

(12) /pi/ 'thicken' *vs.* /pii/ 'thickened, plenty'

(13) /kɔ/ 'go' *vs.* /kɔɔ/ 'went, red'.

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 for the oral and nasal 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 from previous work 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 (Clairet 2008, Delvaux et al. 2008, d'Imperio et al. 2008), and in their acoustic, articulatory or perception contributions (Maeda 1993, Delvaux et al. 2002, Montagu 2002, Montagu 2004, Delvaux 2006, Beddor 2007, Menard et al. 2007, Amelot et al. 2008, Delvaux 2009), 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 analyzes both short and long vowels of the two (oral-nasal) phonological classes. This is one of the main reasons for this study. Nasals in Twi have also remained under-studied or received very little attention in the literature, so this investigation is a contribution to research on oral-nasal comparison that has been extensively studied in a good number of languages.

The current study, based on acoustic data not on articulatory data, will examine segmental durations and formants of the two phonological classes. The paper is organized as follows. In Section 2, I describe the method used for the durational and spectral analyses. The results, as well as the discussion, are found in Section 3. The conclusion is presented in Section 4.

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 Professional Solid State Recorder PMD660. The recordings were done at a self-selected speaking rate in an anechoic room at the laboratory of the Strasbourg Phonetics Institute (Institut de Phonétique de Strasbourg). The randomised list of utterances was produced at least 10 times by each speaker.

First, by means of a PRAAT (Boersma & Weenink, 2006) 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 and 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. Statistical analyses (ANOVAs) were carried out on all measures obtained from the speakers ($p \leq 0.01$). Here are some examples of monosyllabic words from the corpus:

(14) /ka/ ‘bite’ vs. /kɑ̃/ ‘say’, ‘drive’

(15) /kaa/ ‘bit’ vs. /kɑ̃ɑ̃/ ‘said’, ‘drove’

(16) /tʊ/ ‘throw’, ‘buttocks’ vs. /tʊ̃/ ‘roast’, ‘bake’

(17) /tʊʊ/ ‘threw’ vs. /tʊ̃ʊ̃/ ‘roasted’, ‘baked’

(18) /pu/ ‘vomit’ (animals) vs. /pũ/ ‘smoke’ (fish, meat)

(19) /puu/ ‘vomited’ vs. /pũũ/ ‘smoked’ (fish, meat)

3. Results and discussion

3.1. Durational data analyses

Vowel data comparison of absolute values in the oral and nasal groups reveals that the nasal vowels are systematically longer than the oral counterparts for both short and long vowels, for all the subjects. This is in agreement with previous findings on vowel durations (Jha 1985, Whalen & Beddor 1989, Duez 2006, Lovatto et al. 2007, Delattre & Mannot 2009).

As depicted in figures 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 (low standard deviations of 14 ms and 23 ms) for the short and long respectively for Speaker 1. The corresponding measures for the second speaker are 58 ms and 124 ms (standard deviations of 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/.

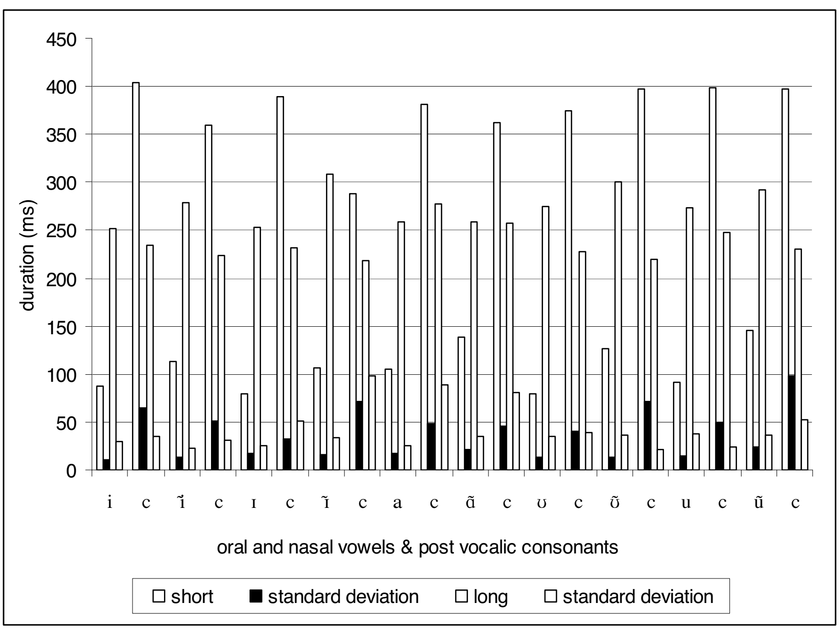

Figure 1. This figure shows average oral vowel, nasal vowel and post-vocalic consonant durations and standard deviations for the first speaker (ms)

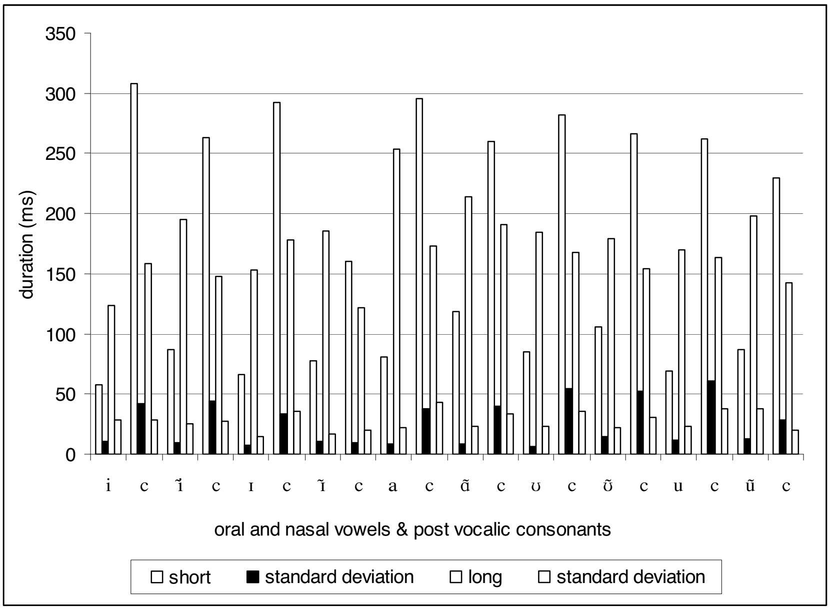

Figure 2. This figure shows average oral vowel, nasal vowel and post-vocalic consonant durations and standard deviations for the second speaker (ms)

Relative values show that in the VC domain phonologically short vowels are followed by phonetically long consonants. As shown in Adu Manyah (2003), differences in consonant duration between short and long oral vowels are statistically significant (p>0.001).

With regards to phonologically long oral vowels, three cases can be observed: the post-vocalic consonant is, either 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. The durational figures for Speaker 1 are: 279 ms and 223 ms, 293 ms and 231 ms for /ɪ̃/ and /ũ/ respectively. The corresponding durational data for the second speaker are 195 ms and 148 ms for /ɪ̃/, 214 ms and 191 ms for /ɑ̃/ and 198 ms and 143 ms for /ũ/ (see figures 1 and 2 again).

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. For the short nasal vowels /ĩ/, /ɑ̃/, /ũ/ we have the following ratios: 0.31, 0.38, and 0.37 for Speaker 1. The data for the second speaker are 0.33, 0.45, and 0.38. The corresponding data for the short oral vowels /i/, /a/, /u/ are 0.22, 0.27, 0.23 for the first speaker and 0.18, 0.27 and 0.26 for the second speaker. We can notice, by comparing the ratios, that the nasal category of vowels registers higher ratios than the oral category for both speakers.

Differences in consonant duration between long and short vowels have also been attested for in the dialects of Modern Swedish (Schaeffling & Wretling. 2003). The authors further posit that there is a complementarity pattern whereby the long vowel+consonant (V:C) sequences have the tendency of possessing almost the same duration as the short vowel+consonant (VC:) sequences. According to their findings the VC: 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. However, 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 the 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 /ʊ̃/ and /ũ/, for speaker 1. The short vowel /ɪ̃/ + consonant sequence has an average duration of 473 ms as compared to 502 ms for the long vowel /ɪ̃ɪ̃/ + consonant type. The average is 395 ms and 526 ms for the pair short /ɪ̃/ + consonant and long /ɪ̃ɪ̃/ + consonant, and 502 ms compared to 517 ms for short /ã/ + consonant and long /ãã/ + consonant. Concerning the two nasal back vowels /ʊ̃/ and /ũ/, the average values are 524 ms and 543 ms respectively for the category of short vowel + consonant and 520 ms and 524 ms for the category of long vowel + consonant.

For the second speaker, the short /ɪ̃/ + consonant (238 ms) *vs*. long /ɪ̃ɪ̃/ + consonant (308 ms), short /ã/ + consonant (378 ms) *vs* long /ãã/ + consonant (405 ms) and /ũ/ + consonant (316 ms) *vs* /ũũ/ + consonant (341 ms) series, conform to the model. Concerning the other two nasal vowels, it is rather short /ɪ̃/ and /ũ/ + consonants (350 ms and 372 ms) that are longer than /ɪ̃ɪ̃/ and /ũũ/ + consonants (343 ms and 333 ms). (See figures 1 and 2 again). Thus, the observation on the complementarity pattern is in accordance with results obtained for Bolognese where it is shown that the phenomenon is only partially applicable (Hajek 1994).

Two remarks can be made to conclude this section. First, the findings of this study on phonological durational contrasts and the contribution of the post-vocalic consonant to distinguish the two phonological classes have already been documented on studies in Thai (Mixdorff et al. 2002) and Bolognese (Hajek 1994). Second, in the group of long vowels, figures 1 and 2 clearly show that post-vocalic consonant durational values are close to vowel durations. The difference between the two average values is not statistically significant *(p=ns).*

Even though the two speakers have different absolute values for vowel and consonant durations, which can be explained by individual speaking rates (the second speaker has a relatively faster speaking rate than the first speaker as illustrated in figures 1 and 2), we observe, thanks to relative data analysis, that it is basically the same strategy that is adopted by the two speakers to preserve phonological contrasts and distinguish between the two phonological sets. A comparison of the oral and nasal classes shows that the two speakers maintain the proportion of the vowel relatively stable within the VC syllable domain: a difference of around 10 % separates both phonologically short and long categories. Such results concerning oral vowels have been previously reported for unrelated languages like Swedish and Wolof (Sock et al. 1996).

3.2. Spectral data analyses

As illustrated in figures 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 (Delvaux et al. 2002). 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 figures 3 and 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).*

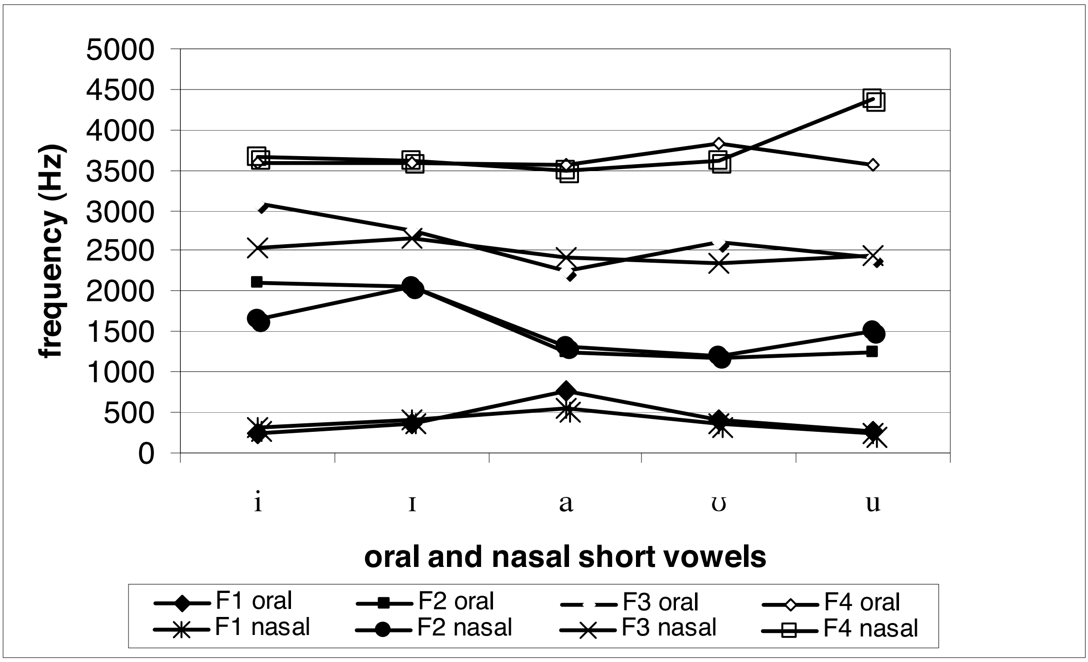

Figure 3. This figure shows formant values for short oral and nasal vowels /i ɪ a ʊ u/ for Speaker 2

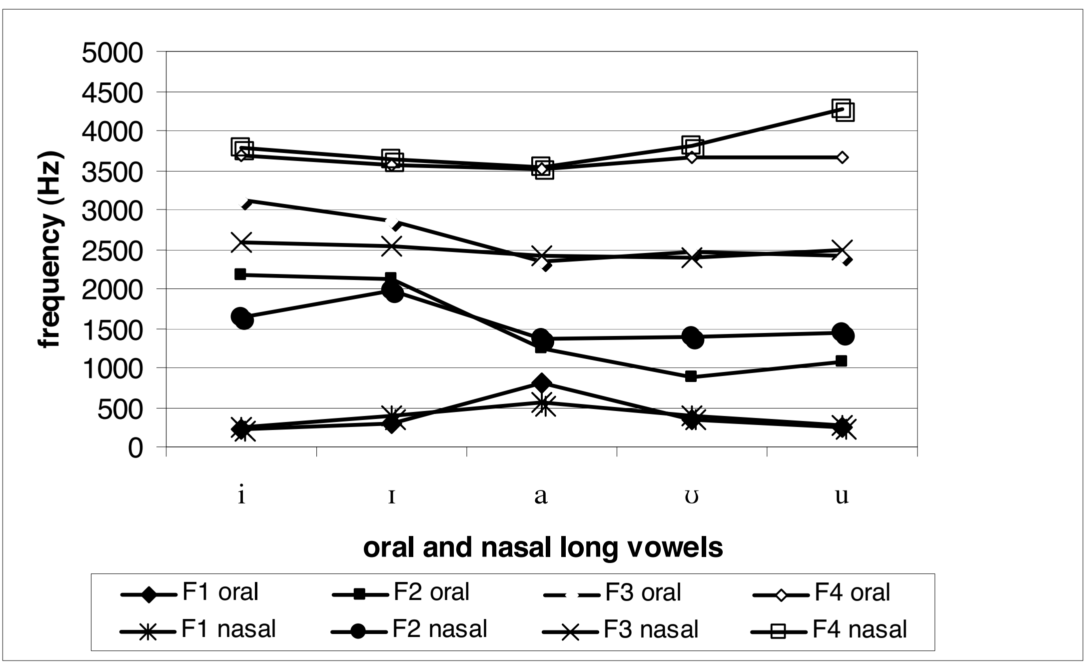

Figure 4. This figure shows formant values for long oral and nasal vowels /iː ɪː ɑː ʊː uː/ for Speaker 2

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 (Stevens. 1985, Menard et al. 2007). 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 figures 3 and 4 again).

In order to take a closer look at the three extreme vowels of the vowel triangle /i, a, u/, the settings of the formant parameters were fixed for the sound editor, oral and nasal curves were plotted on the same graph allowing comparison of analytical data. Comparing formant values for oral and nasal vowels, 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 (figure 5).

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 figures 3 and 4.

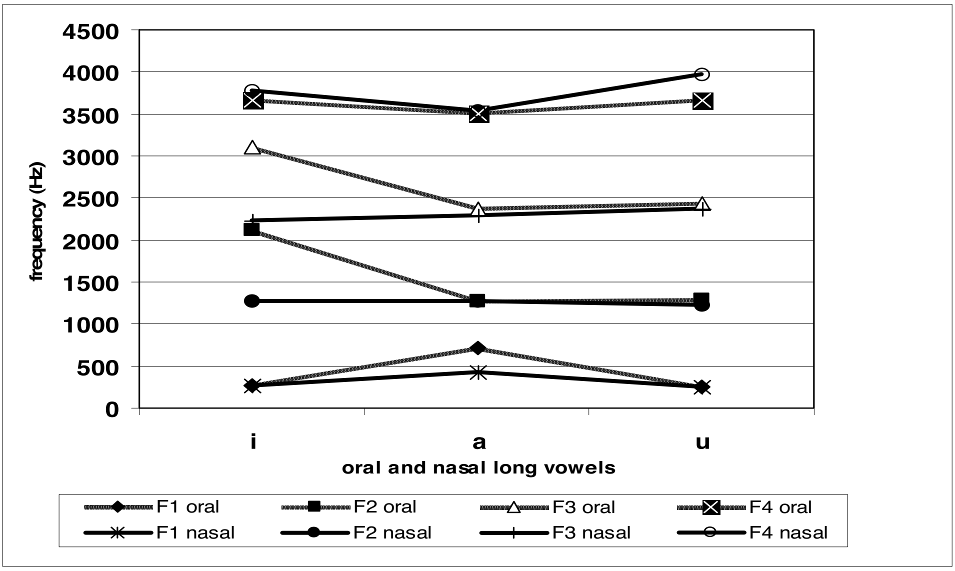

Figure 5. Oral and nasal long vowels: Comparison of formant values for the three extreme vowels of the vowel triangle /i, a, u/ for the second speaker

Assuming also that vowel dispersion refers to how dispersed the vowels are in phonological space, the scatter plots (F1 on the ordinate, the vertical axis and F2 on the abscissa, the horizontal axis) prepared to represent data, clearly illustrate that the oral vowels /i, a, u/ are less widely dispersed in phonological space than the nasal counterparts. The phonological space is defined by the maximum and minimum values of F1 and F2. This is found to be reduced for the oral vowels. In this dispersion, each vowel's distance from the average of all vowel formants is not taken into account (see figures 6 and 7).

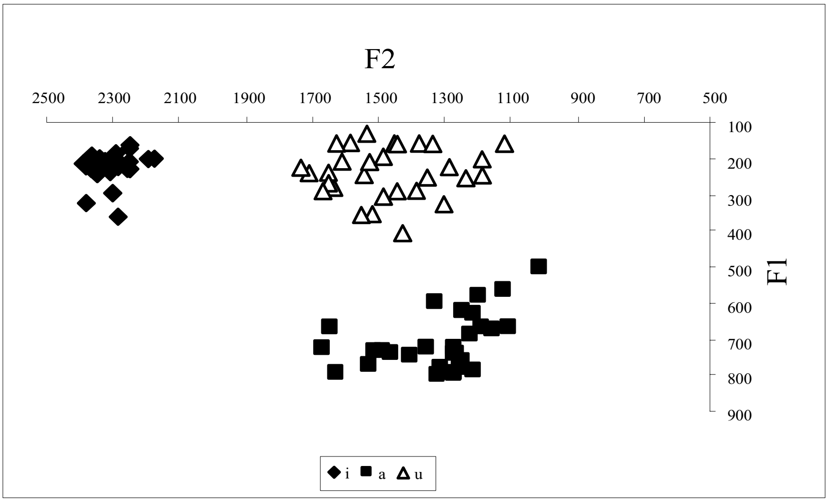

Figure 6. Dispersion of long nasal vowels /ĩ, ɑ̃, ũ/ for Speaker 2 (Hz)

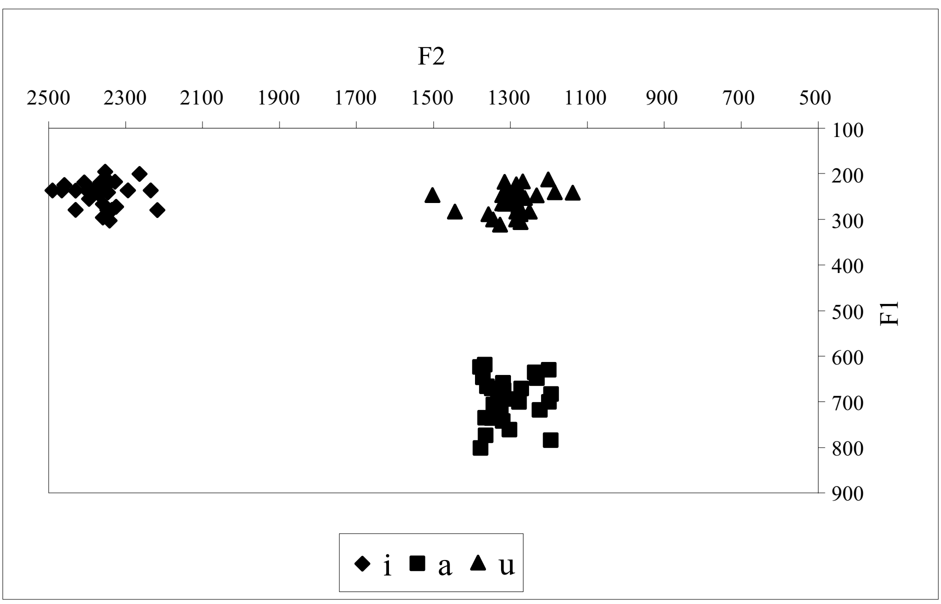

Figure 7. Dispersion of long oral vowels /i, a, u/ for Speaker 2 (Hz)

4. Conclusion

This study has shown on the basis of acoustic data, that nasal vowels in Twi are longer than their oral counterparts in both the short and long contexts. Thus the current study supports the durational analyses of orals and nasals reported in previous studies (Jha 1985, Whalen & Beddor 1989, Duez 2006, Lovatto et al. 2007, Delattre & Mannot 2009). 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 behavior. Phonologically short vowels are followed by phonetically long consonants in the oral and nasal contexts.

Acoustic evidence also shows that the formant values are generally lower for the nasal vowels, particularly the formant F2 in this study, 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 high back vowel /u/ in that 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 (oral and nasal vowels) 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 the nasal vowels are more widely dispersed than the oral vowels in phonological space.

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