http://dx.doi.org/10.4314/gjl.v6i1.67

AN ACOUSTIC INVESTIGATION OF THE DURATION OF VOWEL NASALIZATION IN GA

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Abstract

Relationship between vowel quality and nasalization has seen a number of investigations in languages with results indicating that the duration of nasalization varies with the quality of vowel. While some of the investigations reported that greater velopharyngeal opening occurs in mid-high and high back vowels in some languages, other investigation results show that low vowels are nasalized with greater velopharyngeal opening than high vowels in some other languages. It has been argued that in vowel nasalization low vowels are preferred because low vowels have longer duration in that long vowels are more likely to be nasalized than short vowels. This study sets out to investigate the relationship between the quality of vowels and nasalization in Ga by using acoustic measures. The study makes use of four native Ga speakers' production of oral and nasal vowels in words. The words were recorded in a carrier frame and was analysed using PRAAT. The results indicate that nasal vowels have longer duration than oral vowels and the nasal part of the nasal vowel is longer in high vowels than it is in the low vowels. Generally, the nasal portion of the nasal vowel has longer duration than the oral portion of the vowel. Also, the Front vowels seem to have longer nasal portions than the back vowels. Another observation from the analysis was that the nasal vowels have higher F1 and F2 values than the oral vowel. Thus, the amount of nasalization in Ga vowels is influenced by the quality of vowel.

Keywords: Nasalization, Nasal, Duration, Acoustic, Formants, PRAAT, Vowel quality

1. Introduction

The aim of this study is to acoustically analyse the oral and nasal vowels of the Ga language. The study investigates the relationship between vowel quality and nasalization in Ga. It investigates the duration and also the quality in terms of first and second formant (F1 and F2) values of Ga oral and nasal vowels. It seeks to do a case study of how the duration of vowels affects vowel nasality. Ga is the language of the Ga people in Accra, the seat of the government of Ghana. It is a Kwa Language in which nasalization and tone are phonemic. It is a tone language which has an inventory of seven phonemic oral vowels. It also has five contrasting nasalized vowels which contrast meaning with changes in tone as well. Thus, Ga uses twelve phonemic vowels: /i/, /e/, /ɛ/, /ɑ/, /ɔ/, /o/, /u/, /ĩ/, /ɛ̃/, /ɑ̃/, /ɔ̃/, /ũ/, which may be used with varying tones in utterances to create different meanings, Akpanglo-Nartey R. (2011). All the oral vowels except the mid front vowel /e/ and mid back vowel /o/, contrast with nasalized counterparts to cause lexical distinctions. The phonemic status of the nasal vowels is evident in the following pairs of Ga words:

Table 1: Phonemic status of Ga nasal vowels

Word	Phonetic transcription	Gloss
shi	**[ʃí]**	to pound
shi	**[ʃĩ́]**	to leave
gbɛ	**[gbɛ́]**	pot
gbɛ	**[gbɛ̃́]**	ethnic mark
ka	**[ká]**	to nail
ka	**[kã́]**	to stir / earthenware bowl
gba	**[gbà]**	narrated

gba	**[gbɑ̃]**	married
shɔ	**[ʃɔ́]**	to kiss
shɔ	**[ʃhɔ́]**	to snatch
kpɔ	**[kpɔ]**	knot
kpo	**[kpɔ́]**	to save/rescue
fu	**[fù]**	become mouldy
fu	**[fù̀]**	to bury/smell

While the majority of the oral vowels may be preceded by any of the consonant phonemes of Ga, phonemic nasal vowels may not be preceded by the consonants /p/, /b/, /l/, /ɪ/, /j/, /ʤ/, /g/, /kp/, and /w/. Aside the phonemic nasal vowels, there is nasalization of vowels that occur when nasal consonants in Ga precede vowels. In other words nasalization spreads rightwards from a nasal consonant onset to the vowel (with the exception of /ɑ/ in **ŋaa** [**ŋɑ̀ː**] 'advice'. Vowels acquire nasality when preceded by nasal consonants. On the other hand, a vowel followed by a nasal consonant may not be nasalized eg. [**flɛŋː**] 'sitting on the fence', [**pɛmpɛoo**] 'small'.

In Ga, vowel length is as important as the phonemes in that, duration is phonemic in both the oral and nasalized vowels. The duration of vowels in the syllable distinguishes between words lexically and grammatically in other instances. For instance, **fa** [fà] 'borrow'; **faa** [fàː] 'river or the act of borrowing'; **da** [dà] 'big or grow'; **daa** [dà] 'the act of growing'; **tsa** [tʃà] 'dig out'; **tsaa** [tʃàː] 'the act of digging'. Negation may also be expressed by varying the length of the vowel: for instance, **be** [bé] 'quarreled' but [béː] 'did not quarrel'; **ye** [jé] 'eat' but [jéː] 'did not eat'.

A nasal vowel is produced by establishing an acoustic coupling between the oral and the nasal tract. This is achieved by lowering the velum to allow air flow through both the oral and the nasal tracts simultaneously. Acoustically nasalization is associated with the reduction in intensity of the first formant due to the addition of the nasal cavity in the production of the vowel. There have been many researches investigating the link between

vowel quality and nasalization with varying results. Al-Bamerni, A. (1983) reports that, greater velopharyngeal opening occurs in mid-high and high back vowels in Gujarati and Hindi. Some of the researchers have concluded that the relationship between vowel height and nasalization is such that low vowels in French are nasalized with greater velopharyngeal opening than high vowels thus concluding that nasalization prefers low vowels over high vowels including Delvaux, P. et al. (2002).

High vowels are said to be nasalized sooner than low vowels because a small degree of velopharyngeal opening can affect the acoustic characteristics of high vowels more than low vowels. Hajek, J. et al. (2000) propose that low vowels are preferred because low vowels have longer duration in that long vowels are more likely to be nasalized than short vowels.

This paper contributes to the discussion on nasalization duration by analysing and describing the oral and nasalized vowels of the Ga language. It examines how vowel quality affects nasalization in Ga and also the duration and intensity of the nasalized vowels. The study answers the questions: how does duration of vowels differentiate between oral and nasal vowel? How does the quality of the vowel affect nasalization in Ga? What is the nature of intensity in the oral and nasal vowels?

2. The Design

This study employs acoustic and qualitative approaches to research in the bid to describe the duration of nasalization in Ga. It uses the acoustic approach which measures physical values of the phenomenon being described. It gives a precise description of the phenomenon using frequency values of formants, intensity and duration of the sounds. The study also used the qualitative approach to research in that it describes the duration of nasalization, looking at the case of Ga.

3. Participants

Data was collected from two male and two female Ga native speakers of ages between 30 and 45 years. These speakers had lived most of their lives in indigenous Ga towns: Teshie, Ga Mashie and Tema. They have no known speech defects or hearing defects. All the speakers are literates in Ga and English languages. They all had their basic education in their native lands and went outside their lands to pursue tertiary education.

4. Data collection

Monosyllabic test words made up of an onset and the oral and nasalized vowel nuclei were recorded in a frame '**kɛɛmɔ…pɛ',** 'say … only'. The test words were written in the Ga orthography. Table 1 above shows all the test words used in the study. A Sony IC recorder and was later acquired on PRAAT at a sampling rate of 41025Khz. The microphone was placed at an angle of about 45 degrees and a distance of about 6 inches from the speakers' lips. The frame with test words were randomized on flash cards and speakers were given 2mins each to familiarize themselves with the test words after which they read the frame presented to them one after another. The speakers read the test words in real sentences and also in the frame in order to help them identify the words especially since tone and nasalization are not marked in Ga orthography. The test words in the frame were said two times each.

In order to avoid variations that may be due to differences in tone, tone factor was held constant. The low tone was used in most of the test words used and where we were unable to get a minimal pair with the low tone, a pair with the high tone was used. For instance, in the case of the vowel /i/, [**fĩ**] and [**fḯ**] with high tones were included in the test words.

5. Acoustic Analysis

The acoustic analysis was done by generating the formant frequencies of oral and nasal vowels from different points within the utterance. The first two formant frequencies were measured from the 25%, 50% and 75% of the sound spectrogram. Also, the intensity of the sounds was measured at the three points within the sound signal where the formant frequency measures were taken. In addition to these, the duration of each sound was measured by enveloping the sound and measuring its length. Samples of the waveforms and spectrograms of the sounds are shown in figures one and two.

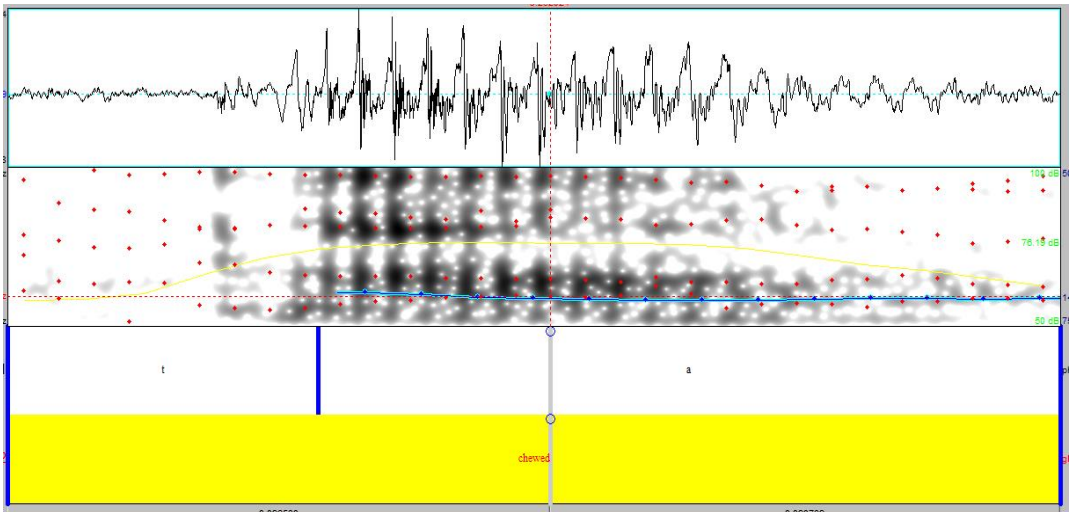

Figure 1: Waveform (top third) and Spectrogram (middle third) of [tà]which shows amplitude on the vertical axis and time on the horizontal axis in the waveform and in the spectrogram, frequency on the vertical axis and time on the horizontal axis.

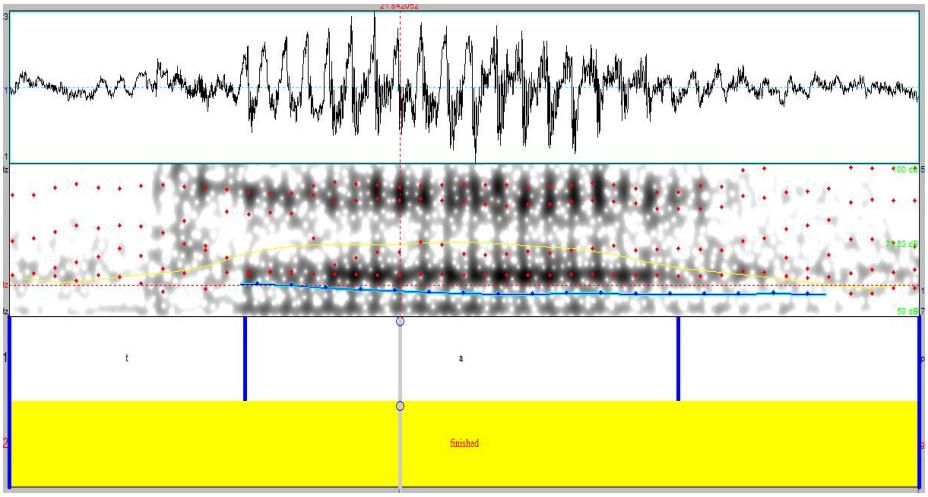

Figure 2: Waveform (top third) and Spectrogram (middle third) of [tà̀] which shows amplitude on the vertical axis and time on the horizontal axis in the waveform and in the spectrogram, frequency on the vertical axis and time on the horizontal axis.

6. Results

The results of this study are discussed in this section. The section discusses the results of the analysis by first of all discussing the duration results then the results of intensity analysis, and then the analysis of formant frequencies.

6.1. Durational Analysis

The data analysis shows that nasal vowels are consistently longer than the oral vowels for all the subjects used. This finding is similar to those of Delattre and Mannot 2009, Lovatto et al 2007, Duez 2006, Jha 1985 Whallen and Beddor 1989, and Manyah 2011. The oral /ɑ/ measures 0.13 seconds and the nasal /ɑ̃/ measures 0.23 seconds for speaker RD where the onset is /b/; with an onset of /t/ the two sounds measured 0.15 and 0.20 seconds respectively; with a /f/ onset they measured 0.13 seconds and 0.18 seconds respectively. When the tones of the words were changed to the high tone, the results showed the same trend for speaker RD: with a /t/ onset /ɑ/and /ɑ̃/sounds measured 0.17 seconds and 0.28 seconds respectively and with a /f/ onset the measures were 0.11 seconds for the oral and 0.22 seconds for the nasal. For the high tone words, the duration of the nasal vowel is almost twice the duration of the oral vowel.

The second speaker AD recorded similar trends as Speaker RD. For this speaker, the oral /ɑ/ with a /b/ onset measured 0.14 seconds while the nasal /ɑ̃/ measured 0.25 seconds. With a /t/ onset the oral /ɑ/ measured 0.13 seconds while the nasal /ɑ̃/ measured 0.20 seconds. With a /f/ onset, the oral /ɑ/ measured 0.13 seconds and the nasal /ɑ̃/ measured 0.17 seconds. With a high tone, the oral /ɑ/ with a /t/ onset measured 0.14 seconds while the nasal /ɑ/ measured 0.29 seconds. With a /f/ onset the oral /ɑ/ measured 0.11 seconds while the nasal measured 0.2 seconds. Again, the duration of the nasal vowel is twice as long as that of the oral vowels.

The duration of the oral and nasal high front vowel /i/ shows that for speaker RD the oral vowel with a /f/ onset measures 0.19 seconds while the nasal vowel measures 0.23 seconds; with a /tʃ/ onset the oral /i/ measured 0.09 seconds while the nasal /i/ measured 0.23 seconds.

Speaker AK recorded an oral /i/ with a /f/ onset that measures 0.09 seconds and a nasal /i/ which measures 0.22 seconds. With a /ʧ/ onset this speaker records an oral /i/ of 0.09 seconds and a nasal /ĩ/ of 0.21 seconds.

These measurements indicate that the nasal vowels measured for the two speakers are twice as long as their corresponding oral vowels.

Measures for the oral and nasal mid front show that nasal /ɛ̃/ is also twice as long as the oral /ɛ/. For speaker RD, the oral /ɛ/ with a /gb/ onset measures0.13 seconds while the nasal counterpart measures 0.24 seconds. For speaker AK, the oral /ɛ/ with a /gb/ onset measures 0.17 seconds while the nasal counterpart measures 0.21 seconds.

The oral and nasal mid back vowel show that nasal /ɔ̃/ is also twice as long as the oral /ɔ/. For speaker RD, the oral /ɔ/ with a /ʃ/ onset measures 0.13 seconds while the nasal counterpart measures 0.24 seconds. With a /f/ onset the oral vowel measured 0.13 seconds while the nasal measured 0.19 seconds. And with a /k/ onset the oral vowel measured 0.1 seconds and the nasal vowel measured 0.24 seconds.

Speaker AK recorded oral /ɔ/ with a /ʃ/ onset that measures 0.11 seconds while the nasal counterpart measures 0.25 seconds. With a /f/ onset the oral vowel measured 0.15 seconds while the nasal measured 0.19 seconds. And with a /k/ onset the oral vowel measured 0.13 seconds and the nasal vowel measured 0.24 seconds.

The study showed that the nasal cues of the vowels in all instances are relatively longer than the oral cues. The only exception to this is in /ɔ̃/ with /k/ and /f/ onsets where the oral cues were longer than the nasal cues. This is shown in Figure 2 below. In Figure 2 the 'X' axis represents the duration while the 'Y' axis represents the vowel type.

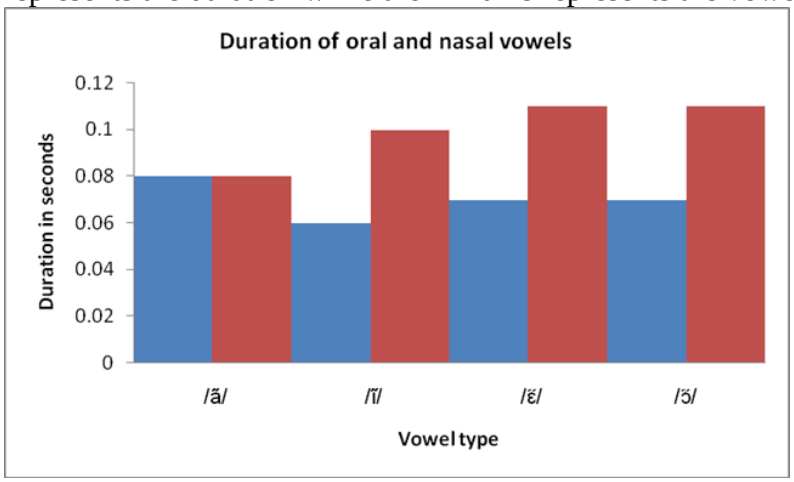

Figure 3: Duration of oral and nasal portions of vowels. The figure shows oral cue of the vowel in blue and the nasal cue in wine. The duration of sounds in seconds is shown on the vertical axis and the vowel types are shown on the horizontal axis.

Averagely, the vowel /ɑ/ for all the speakers shows that the nasal vowel is longer than the oral counterpart by about 0.04 seconds and in the nasal vowel, the nasal portion is longer than the oral portion of the vowel by 0.01 seconds. The vowel /i/ shows similar trends to the vowel /ɑ/ in that the nasal vowel is longer than the oral counterpart by 0.06 seconds, the nasal portion being longer than the oral portion of the nasal vowel by 0.04 seconds. The nasal vowel /ɛ̃/ is longer than the oral counterpart by 0.04 seconds and the nasal portion of it is longer than the oral portion by 0.04 seconds. Similarly, the nasal vowel /ɔ̃/ is longer than the oral vowel by 0.03 seconds and the nasal portion is longer than the oral by 0.04 seconds.

It is realized from the analysis that the duration of the nasal vowel is longest for the mid front vowel, followed by the low back vowel and the mid back vowel. Nasalization is shortest for the mid back vowel which shows the smallest variation (0.03 seconds) between the duration of the oral and the nasal vowel. The analysis indicates that the nasal cues are longer than the oral. The nasal duration of the low vowel is shortest (0.01 seconds) compared to the other vowels where the duration of the nasal portion is about 0.04 seconds.

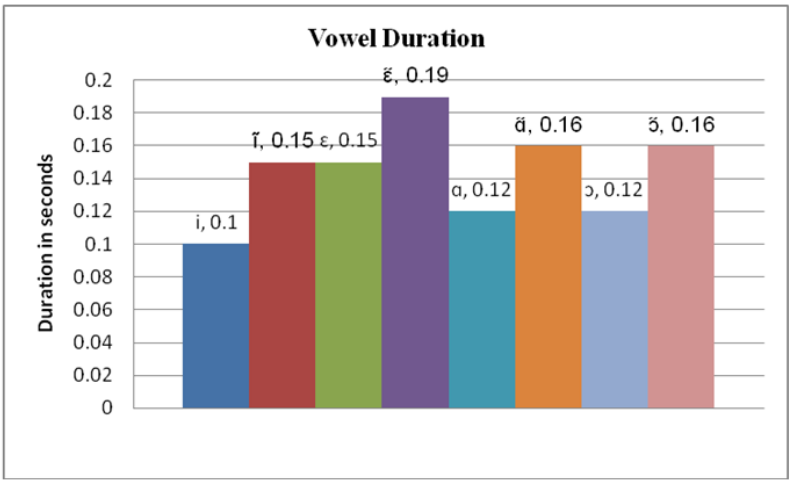

Figure 4: Average duration of oral and nasal cues of vowels. The duration of sounds is shown in seconds on the vertical axis and the vowel types are shown on the horizontal axis.

In a Consonant Vowel (CV) environment the consonants before both the oral and the nasal vowel are relatively shorter than the vowels. The length of the consonant does not seem to be affected by the nasality of the following vowel because there are instances in the data where the consonants are equal in duration for the oral and nasal vowel: in **ba** [bɑ́] the consonant duration is 0.08 seconds; in **fa** [fɑ́] the consonant duration is 0.17 seconds. In other instances, the consonant duration is longer before the nasal vowel than before the oral vowel while in other instances the reverse is true. Thus, the relationship between nasality and consonant duration for the onset is not established in this data.

6.2. Analysis of Intensity

The intensity for /ɑ/ at the 25% point is 77dB. This decreased by the 50% point to 74dB and to 69dB. The nasal started with an intensity of 78dB which decreased to 75dB and to 72dB. /i/ at the 25% point has an intensity of 77dB and this came to 76dB and to 75dB. The nasal /ĩ/ started with 78dB and reduced to 77dB and to 75dB. /ɛ/ has an intensity of 81dB which dipped to 79dB and to 76dB. The nasal /ɛ̃/ starts with 82dB and fell to 81dB and to 62dB. The sound /ɔ/ at the 25% point has an intensity of 80dB which fell to 78dB and to 74dB. The nasal /ɔ̃/ at the 25% point measured 79dB in intensity and this fell to 77dB and to 71dB.

6.3. Analysis of Formants

The analysis of Formants was done by looking at the trends in the first formant frequency (F1) and then the second formant frequency (F2) of the participants. The measures were taken from the 25%, 50% and 75% points (i.e. The first third, the midpoint and the final third) within the utterance.

6.3.1. F1 measurements

For speaker RD, F1 for the oral /ɑ/ rises gradually from 715Hz through 766Hz to 779Hz while the nasal /ɑ̃/ started with 523Hz at the 25% point of utterance and by the 50% point F1 had reduced to 449Hz which further reduced to 367Hz by the 75% point of utterance. Thus, the nasal vowel /ɑ̃/ has relatively lower F1 at the various points than the oral vowel /ɑ̃/.

F1 for /i/ at the point 25% measured 323Hz and reduced to 315Hz at the 50% point and then to 281Hz at the 75% point of the vowel. For the nasal counterpart /ĩ/ F1 measured 365Hz at 25% and reduced to 201Hz at 50% and to 196Hz at 75%. The nasal of /i/ therefore has a relatively higher F1 value than the oral counterpart. It however reduced to a value lower than the oral by the end of the sound.

The vowel /ɛ/ for speaker RD measured 512Hz at 25% and this dipped to 498Hz by the 50% and then dipped further to 426Hz by the 75% point. /ɛ̃/ measured 511Hz at 25%, dipped to 342Hz at 50% and to 266Hz at the 70% point. The nasal /ɛ̃/ has relatively lower F1 values than the oral counterpart throughout the sound. The vowel /ɔ/ is 528Hz at 25% but dips like other vowels to 497Hz at 50% and to 498Hz at 75%. /ɔ̃/ starts with 504Hz at 25%, dips to 447Hz at the midpoint and then 386Hz at 75%. The nasal /ɔ̃/ like the other nasal sounds has a relatively lower F1 values than the oral /ɔ/.

For speaker AK, /ɑ/ starts with 697Hz at 25% then rises to 770Hz at the midpoint and again rises to 779Hz by the 75%. The nasal /ɑ̃/ starts with a lower F1 of 508Hz at 25% and then dips to 429Hz by the midpoint and dips again to 409Hz at the 75% point. The figures show relatively lower F1 values for the nasal sound.

The vowel /ɛ/ for this speaker measured 471Hz at 25% but dips to 451Hz by the midpoint and rises to 474Hz. The nasal /ɛ̃/ measured 380Hz which was reduced by the midpoint, to 365Hz. It again dipped to 340Hz by the 75% point.

The /i/ sound measured 321Hz at the 25% point and this fell to 306Hz by the 50% point and then to 307Hz by the 75% point of the sound. The nasal /ĩ/ measured 396Hz at 25% and reduced to 328Hz at 50% and reduced again to 296Hz. The nasal /ĩ/ unlike other nasals for speaker AK has relatively higher F1 values than the values for the oral.

Sound /ɔ/ has F1 value of 549Hz at the 25% point of the sound and the value reduced to 501Hz by the midpoint of the sound. The value then increased to 529Hz by the 75% point of the sound. The nasal /ɔ̃/ started with a relatively higher F1 of 562Hz but dips to 463Hz at the midpoint and then to 411Hz by the 75% point of the sound.

F1 for speaker NA, /ɑ/ increased gradually from 661Hz through 673Hz at the midpoint and the value here is maintained at the 75% point in the sound. The nasal /ɑ̃/ started with a relatively lower F1 of 620Hz at the 25% point of utterance and by the 50% point F1 had increased to 680Hz which is higher than the F1 value of the oral /ɑ/. F1 further increased to 701Hz by the 75% point of utterance. Thus, the nasal vowel /ɑ̃/ has relatively higher F1 values on the average than the oral counterpart.

The /i/ vowel sound measured 379Hz at the point 25% and increased to 398Hz at the 50% point and then decreased to 355Hz at the 75% point of the vowel. For the nasal

counterpart /ĩ/ F1 measured 351Hz at 25% and increased 356Hz at 50% and decreased again to 270Hz at 75%. The nasal of /i/ therefore has relatively lower F1 values than the oral counterpart.

The vowel /ɛ/ for speaker NA measured 404Hz at 25% and this increased to 530Hz by the 50% and then to 605Hz by the 75% point. /ɛ̃/ measured 506Hz at 25%, dipped to 487Hz at 50% and then to 376Hz at the 70% point. The nasal /ɛ̃/ has relatively lower F1 values at the 50% and 75% points of the sound than the oral counterpart but higher F1 at the 25%.

The vowel sound /ɔ/ for this speaker has F1 of 551Hz at 25% which increases to 579Hz at 50% and then to 576Hz at 75%. /ɔ̃/ starts with 584Hz at 25%, dips to 537Hz at the midpoint and then to 453Hz at 75%. The nasal /ɔ̃/ has a higher F1 value at 25% than the oral counterpart but has relatively lower values at the 50% and 75% points of the sound.

Speaker AJ's, /ɑ/ starts with F1 of 658Hz at 25% then rises to 731Hz at the midpoint and again rises to 777Hz by the 75%. The nasal /ɑ̃/ starts with a lower F1 of 589Hz at 25% and then dips to 555Hz by the midpoint and dips again to 414Hz at the 75% point. The figures show relatively lower F1 values for the nasal sound.

/ɛ/ vowel sound for this speaker measured 451Hz at 25% but dips to 430Hz by the midpoint and to 428Hz. The nasal /ɛ̃/ measured 487Hz which was reduced by the midpoint, to 477Hz. It again dipped to 337Hz by the 75% point. At the 25% and 50% points of the sound, the nasal /ɛ̃/ has relatively higher F1 values than the oral counterpart.

Sound /i/ has F2 of 358Hz at the 25% point and this fell to 331Hz by the 50% point and then increased to 377Hz by the 75% point of the sound. The nasal /ĩ/ measured 380Hz at 25% and reduced to 302Hz at 50% and reduced again to 290Hz. The nasal /ĩ/ has relatively higher F1 values at the 25% point than the F1 value for the oral.

The vowel /ɔ/ has F1 value of 526Hz at the 25% point of the sound and the value increased to 528Hz by the midpoint of the sound. The value then increased again to 550Hz by the 75% of the sound. The nasal /ɔ̃/ started with a relatively lower F1 of 507Hz then increased to 527Hz at the midpoint and then decreased to 460Hz by the 75% point of the sound.

Table 2: F1 Percentages for Vowels

	F1		
vowel	25%	50%	75%
/a/	683	735	752
/ã/	560	529	473
/i/	345	337	330
/ĩ/	320	307	284
/ɛ/	484	475	483
/ɛ̃/	471	418	305
/ɔ/	539	501	538
/ɔ̃/	530	494	430

The average F1 values for all the speakers are plotted in Figures 5, 6, 7, and 8, which show the relationships between the oral vowels and their nasal counterparts. As shown in Figure 5 the oral /i/ vowel starts with F1 of 345Hz and falls slightly to 337Hz and then to 330Hz. The difference between the frequencies at the 25% point and the 50% point is 8Hz and the difference between the 75% point and the 50% point is 7Hz. With the nasal vowel /ĩ/ however the difference between the 50% and the 25% point is 13Hz and the difference between the 75% point and the 25% point is 23Hz. Therefore, the F1 for the nasal vowel has a steeper slope compared with that of the oral vowel /i/. Generally, the nasal vowel shows lower F1 values than the oral vowel. Thus, nasalizing the vowel /i/ is an indication of lowered F1.

The vowel /ɛ/ shows similar F1 movement through the utterance as /i/. The oral vowel shows F1 of 484Hz and about 9Hz higher at the 25% point than the 50% point and the 50% point shows about 8Hz lower value than the value at the 75%. Like the /i/ and /ĩ/ vowels, the nasal /ɛ̃/ has lower F1 values than the oral /ɛ/but the difference at the 75% point is even bigger (78Hz) and this is shown in the slope of F1 chart in Figure 6.

The vowels /ɑ/ and /ɑ̃/ show higher F1 values for /ɑ/ than for /ɑ̃/. Whereas /ɑ/ starts with 683Hz the nasal /ɑ̃/starts with 560Hz, a difference of 123Hz at the 25% point. At the 50% point, there is a difference of 206Hz and a difference of 279Hz at the 75% point. While the oral vowel F1 is rising for this vowel, it is falling for the nasal counterpart.

The vowels /ɔ/ and /ɔ̃/ show higher F1 values for /ɔ/ than for /ɔ̃/. Whereas /ɔ/ starts with 539Hz the nasal /ɔ̃/ starts with 530Hz, a difference of 9Hz at the 25% point. At the 50% point, there is a difference of 7Hz and a difference of 8Hz at the 75% point. The nasal vowel F1 falls through the utterance with a difference of 36Hz between the 25% and 50% and a difference of 64Hz between the 50% and the 75% points. This shows a significant drop as shown in Figure 8.

The values for F1 between the oral vowels and their nasal counterparts show that the nasal vowels have lower values than the oral vowels. Also, the nasal vowels have F1 values which fall significantly through the 25%, 50% and 75% points in the vowels.

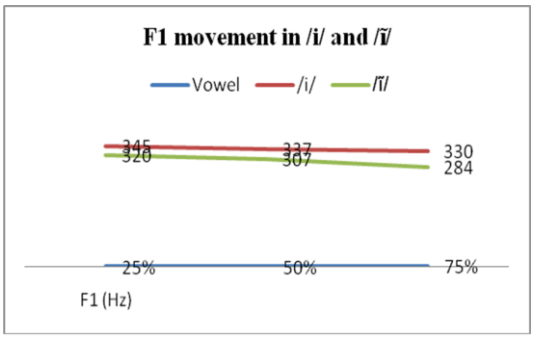

Figure 5: F1 for /i/ and /ĩ/

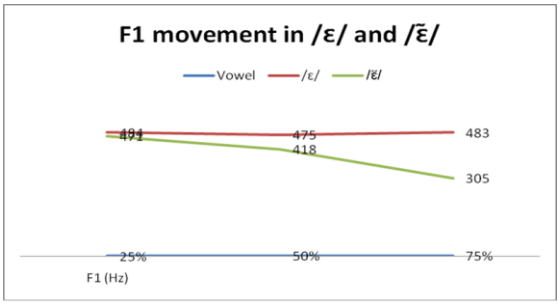

Figure 6: F1 for /ɛ/ and /ɛ̃/

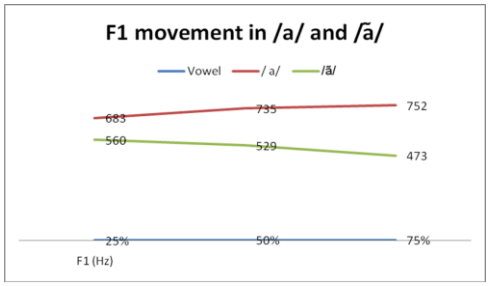

Figure 7: F1 for /ɑ/ and /ɑ̃/

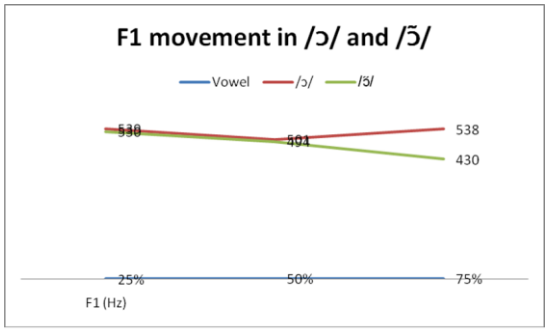

Figure 8: F1 for /ɔ/ and /ɔ̃/

6.3.2. F2 Measurements

The Second Formant (F2) frequency for each of the sounds under discussion was measured from the first third, halfway and the last third of the sound signal.

Speaker RD, F2 for the oral /ɑ/ rises gradually from 1585Hz through 1657Hz to 1724Hz while the nasal /ɑ̃/ started with 1372Hz at the 25% point of utterance and by the 50% point F1 had reduced to 1340Hz which further reduced to 1327Hz by the 75% point of utterance. Thus, the nasal vowel /ɑ̃/ has relatively lower F2 at the 25%, 50% and 75% points than the oral vowel/ɑ/.

The vowel /i/ at the point 25% measured 1916Hz and reduced to 1722Hz at the 50% point and then to 1717Hz at the 75% point of the vowel. For the nasal counterpart /ĩ/ F2 measured 1873Hz at 25% and reduced to 1569Hz at 50% and to 1492Hz at 75%.

The vowel /ɛ/ for speaker RD measured 2049Hz at 25% and this rose to 2078Hz by the 50% and then dipped to 2047Hz by the 75% point. /ɛ̃/ measured 1995Hz at 25%, rose to 2027Hz at 50% and to 1678Hz at the 70% point. The nasal /ɛ̃/ has relatively lower F2 values than the oral counterpart throughout the sound.

The vowel /ɔ/ is 528Hz at 25% but dips like other vowels to 497Hz at 50% and to 498Hz at 75%. /ɔ̃/ starts with 1266Hz at 25%, dips to 1163Hz at the midpoint and then 1269Hz at 75%. The nasal /ɔ̃/ has a relatively higher F2 values than the oral. It starts with 1420Hz at 25% and is reduced to 1260Hz at 50% is increased again to 1413Hz at the 75% point.

For speaker AK, F2 for /ɑ/ starts with 1423Hz at 25% then rises to 1522Hz at the midpoint and decreases to 1468Hz by the 75%. The nasal /ɑ̃/ starts with a lower F2 of 1353Hz at 25% and then dips to 1253Hz by the midpoint and rises to 1283Hz at the75% point.

The vowel /ɛ/ measured 1829Hz which was raised by the midpoint, to 2030Hz. It again increased to 2225Hz by the 75% point. The nasal /ɛ̃/ for this speaker measured F2 of 1633Hz at 25% which dips to 1436Hz by the midpoint and rises to 1521Hz.

F2 for the vowel /i/ measured 1925Hz at the 25% point and this fell to 1919Hz by the 50% point and then to 1886Hz by the 75% point of the sound. The nasal /ĩ/ measured 1935Hz at 25% and reduced to 1872Hz at 50% and reduced again to 1849Hz at 75%.

The vowel /ɔ/ has F2 value of 1392Hz at the 25% point of the sound and the value reduced to 1265Hz by the midpoint of the sound. The value then increased to 1355Hz by the 75% of the sound. The nasal /ɔ̃/ started with a relatively higher F2 of 1430Hz but dips to 1423Hz at the midpoint and then to 1362Hz by the 75% point of the sound.

F2 for speaker NA, /ɑ/ increased gradually from 1328Hz through 1368Hz at the midpoint to 1392 at the 75% point in the sound. The nasal /ɑ̃/ started with a relatively lower F2 of 1143Hz at the 25% point of utterance and by the 50% point F2 had increased to 1147Hz. F2 further increased to 1305Hz by the 75% point of utterance.

The vowel /i/ measured 1328Hz at the point 25% and increased to 1367Hz at the 50% point and then increased to 1392Hz at the 75% point of the vowel. For the nasal counterpart /ĩ/ F2 measured 2257Hz at 25% and decreased to 2172Hz at 50% and decreased again to 2054Hz at 75%. The vowel /ɛ/ for speaker NA measured 1291Hz at 25% and this increased to 1622Hz by the 50% and then to 1666Hz by the 75% point.

/ɛ̃/ measured 1463Hz at 25%, increased to 1713Hz at 50% and then to 1775Hz at the 70% point. The vowel /ɔ/ is 1035Hz at 25% but dipped to 899Hz at 50% and then to 888Hz at 75%. /ɔ̃/ starts with 979Hz at 25%, increases to 1038Hz at the midpoint and then dips to 907Hz at 75%.

Speaker AJ's, /ɑ/ starts with F2 of 1392Hz at 25% then rises to 1488Hz at the midpoint and again rises to 1537Hz by the 75% point. The nasal /ɑ̃/ starts with a lower F2 of 1284Hz at 25% and then rises to 1361Hz by the midpoint and rises again to 1435Hz at the 75% point. The figures show relatively lower F2 values for the nasal sound.

The F2 for vowel /ɛ/ for this speaker measured 1630Hz at 25% which rises to 1772Hz by the midpoint and then to 1790Hz by the 75% point. F2 for the nasal /ɛ̃/ measured 1701Hz at the 25% point and this rose to 1899 by the midpoint, and to 2044Hz by the 75% point.

The vowel /i/ F2 measured 1992Hz at the 25% point and this fell to 1988Hz by the 50% point and then to 1937Hz by the 75% point of the sound. The nasal /ĩ/ F2 measured 2114Hz at 25% and reduced to 2035Hz at 50% and then rose to 2050Hz.

The vowel /ɔ/ has F2 value of 969Hz at the 25% point of the sound and the value decreased to 918Hz by the midpoint of the sound and then to 917Hz by the 75% point of the sound. The nasal /ɔ̃/ started with a relatively lower F2 of 1033Hz then decreased to 976Hz at the midpoint and then to 950Hz by the 75% point of the sound.

Table 3: F2 Vowel Percentages

	F2		
Vowel	25%	50%	75%
/ɑ/	1507	1509	1530
/ɑ̃/	1288	1275	1337

/i/	1973	1923	1999
/ĩ/	**1845**	**1875**	**1829**
/ɛ/	**1774**	**1875**	**1932**
/ɛ̃/	1698	1769	1705
/ɔ/	1166	1061	1107
/ɔ̃/	1216	1174	1158

The average F2 values for all the speakers are plotted in Figures 9, 10, 11, and 12, which show the relationships between the oral vowels and their nasal counterparts. Figure 9 shows F2 values for the oral /i/ vowel which starts with 1973Hz and falls slightly to 1923Hz and then rises to 1999Hz. The F2 for the nasal vowel /ĩ/ is lower at the 25% (1845Hz) and this rose slightly to 1875Hz and then fell again to 1829Hz. Generally, the nasal vowel shows lower F2 values than the oral vowel. Thus, nasalizing the vowel /i/ brings about lowered F2.

The vowel /ɛ/ shows similar F2 movement through the utterance as /i/. The oral vowel shows F2 of 1774Hz at the 25% point and this rose to 1875Hz and then dipped to 1829Hz at the 75% point. Like the /i/ and /ĩ/ vowels, the nasal /ɛ̃/ has significantly lower F2 values than the oral /ɛ/ and this is clear in Figure 10.

Figure 11 shows the graph F2 values for the vowels /ɑ/ and /ɑ̃/. As is shown the oral /ɑ/ has higher F2 values than the nasal/ɑ̃/. Whereas /ɑ/ starts with 1507Hz the nasal starts with 1288Hz, a difference of 219Hz at the 25% point. At the 50% point, there is a difference of 234Hz and a difference of 293Hz at the 75% point between the oral and the nasal.

The vowels /ɔ/ and /ɔ̃/ unlike other vowels discussed show higher F2 values for/ɔ̃/ than /ɔ/. Whereas /ɔ/ starts with 1166Hz the nasal /ɔ̃/ starts with 1216Hz, a difference of 50Hz at the 25% point. At the 50% point, there is a difference of 113Hz and a difference of 51Hz at the 75% point.

The values for F2 between the oral vowels and their nasal counterparts show that the nasal vowels have lower values than the oral vowels except with the vowels /ɔ/ and /ɔ̃/.

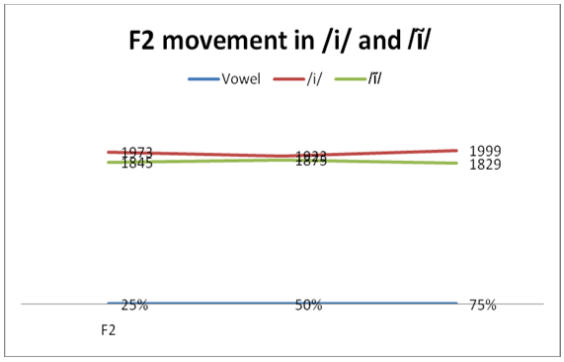

Figure 9: F2 of /i/ and /ĩ/

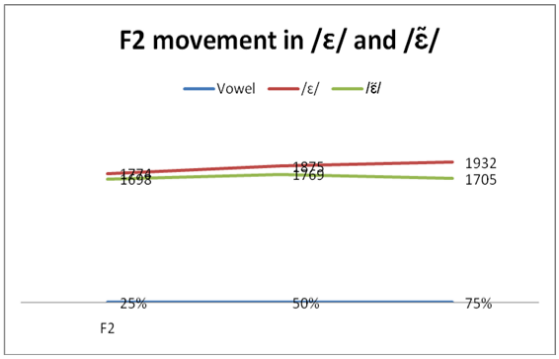

Figure 10: F2 of /ɛ/ and /ɛ̃/

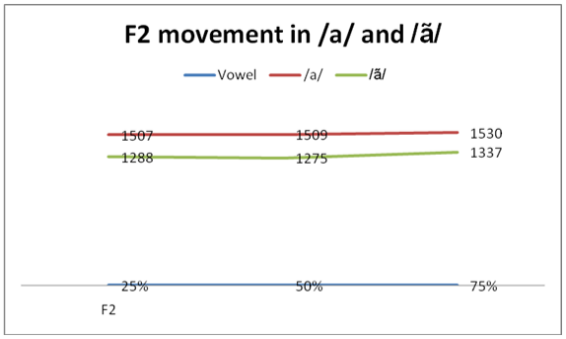

Figure 11: F2 of /ɑ/ and /ɑ̃/

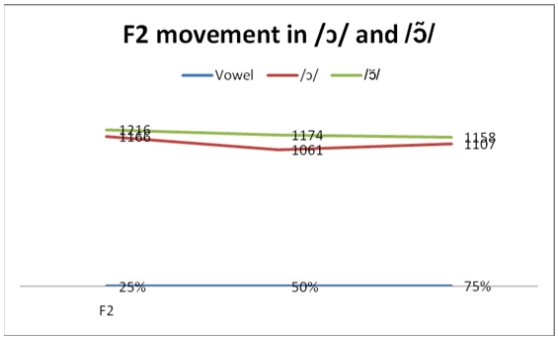

Figure 12: F2 of /ɔ/ and /ɔ̃/

7. Discussion and Conclusion

This study aimed at investigating the duration effect of nasalization in Ga vowels. It is also to find how the nasal vowels differ acoustically from the oral vowels in terms of frequency and intensity. The finding of the study is to be a contribution to discussions on vowel nasalization on languages.

7.1. The Duration of Nasalization

Although observations made from the results of this study are solely on absolute values, it is evident that nasalization in all instances is very long in the sense that the nasal cues of the vowels are relatively longer than the oral cues. The only exception to this is in /ɔ̃/ with /k/ and /f/ onsets where the oral cues were longer than the nasal cues. The nasal vowel /ɑ̃/ is longer than the oral counterpart by about 0.04 seconds and in the nasal vowel, the nasal portion is longer than the oral portion of the vowel by 0.01 seconds. Similarly, the nasal vowel is longer than the oral counterpart by 0.06 seconds, the nasal portion being longer than the oral portion of the nasal vowel by 0.04 seconds. The nasal vowel /ɛ̃/ is longer than the oral counterpart by 0.04 seconds and the nasal portion of it is longer than the oral portion by 0.04 seconds. Similarly, the nasal vowel /ɔ̃/ is longer than the oral vowel by 0.03 seconds and the nasal portion is longer than the oral by 0.04 seconds.

It is realized from the analysis that the duration of the nasal vowel is longest for the high front vowel, though the high front vowel is not the longest vowel produced by the respondents. In fact, the high front vowel seems to be the shortest vowel produced i.e. 0.1 seconds. The mid front vowel is relatively longer than all the other vowels (0.15 seconds) but nasalization in this vowel is not as long as that of the high front vowel. The duration of nasalization of the mid front vowel is second to that of the high front vowel in length and is followed the low central vowel /ɑ/. Nasalization is shortest for the mid back vowel which shows the smallest variation (30 milliseconds) between the duration of the oral and the nasal vowel. The oral and nasal portions of the nasal vowels show that the nasal portions are longer than the oral. The nasal duration of the low vowel is shortest (10 milliseconds) compared to the other vowels where the duration of the nasal portion is about 0.04 seconds and this is in contrast with what Hajek, J. and Maeda, S. (2000) and Delvaux P. et al (2002) reported in French that low vowels are more likely to be nasalized.

In a Consonant Vowel (CV) environment the consonant before both the oral and the nasal vowel are relatively shorter than the vowels. The length of the consonant does not seem to be affected by the nasality of the following vowel because there are instances in the data where the consonants are equal in duration for the oral and nasal vowel: in **ba** [bɑ̃] the consonant duration is 0.08 seconds; in **fa** [fɑ̃] the consonant duration is 0.17 seconds. In other instances, the consonant duration is longer before the nasal vowel than before the oral vowel while in other instances the reverse is true. Thus, the relationship between nasality and consonant duration for the onset is not established in this data.

The intensity values from the data indicate that the nasal vowels have slightly higher intensities than the oral vowels except for the mid back vowel where the oral vowel has a relatively higher intensity than the nasal. In all cases, the intensity was high at the 25% and by the 75% point the intensity is reduced. Thus, intensity is a cue to the oral/nasal contrast in the vowels of Ga.

The values for F1 between the oral vowels and their nasal counterparts show that the nasal vowels have lower values than the oral vowels. Also, the nasal vowels have F1 values which fall significantly through the 25%, 50% and 75% points in the vowels. This is also true for the F2 values of all the vowels except the mid back vowel. This indicates that while the nasalized front vowels are made less front than the oral counterparts, the nasalized mid back vowel is made less back than the oral counterpart. Also, the nasal vowels are made with a slightly higher tongue height than their oral counterparts.

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