

## Vowel Quality Effects on Fundamental Frequency in Ghanaian English

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### Abstract

This study presents some more evidence from Ghanaian English for the existence of Intrinsic Fundamental Frequency IF0 in both the front vowels and back vowels, which may differ other English varieties. Data was recorded from five male and five female speakers of Ghanaian English who spoke English test words in 'hVd' phonetic environments in a carrier sentence: 'say ----- again' into PRAAT software with the help of a head-mounted Shure microphone. Extracted F0, F1 and F2 values of the vowels were taken from onset to offset. The IF0 values were calculated by subtracting the F0 of the low vowel from that of the high vowels and this was done for each vowel from the onset to the offset where pitch drops steadily in the words used. The IF0 of the speakers were compared with IF0 of other English varieties in the literature. The analysis indicated positive IF0 in both high and low pitch sections of the front vowels although there is a reduction in the IF0 values for the female speakers. The back vowels for the females on the other hand, showed positive IF0 values at the low pitch sections of the vowels indicating no neutralization of IF0 unlike what happens in the front vowels for the same group of speakers. In the front vowels, the male speakers showed a reduction of IF0 in mid pitch regions but at the low pitch regions there is neutralization of the IF0. There is however, no neutralization of IF0 in the low pitch regions for the back vowels. The study concludes that although there is the presence of IF0 in Ghanaian English, neutralization of the phenomenon in low pitch is not consistent in the front and back vowels for male and female speakers.

**Keywords:** *Intrinsic Fundamental frequency, Ghanaian English, acoustic analysis, neutralization of IF0*

### Introduction

This study investigates the phenomenon of Intrinsic fundamental frequency (IF0) in Ghanaian English and pays attention to the gradient nature of IF0 in comparison with IF0 in American English. The study determines the size of IF0 in the English language for males and females and compares the results to IF0 sizes of native English already reported in the literature. The size of IF0 in the English spoken as a second language by Ghanaians found to be different from other English varieties would support the view that IF0 is a variable that languages choose to enhance the differences between vowels (Diehl & Kluender 1989, Kingston 1993).

IF0 is said to be a phenomenon in vowel systems whereby high vowels show a tendency of being produced with higher fundamental frequency than low vowels (Peterson & Barney, 1952; Lehiste & Peterson, 1961; Fisher-Jorgensen, 1990; Whalen & Levitt, 1995). This phenomenon has been found to be a universal phenomenon in the sense that it was found to occur in all languages in which a study on IF0 was carried out (Whalen & Levitt, 1995). Studies carried out on the phenomenon showed that the phenomenon is gradient in most languages so that the F0 of high vowels were found to be higher than those of mid and low

vowels and F0 of low vowels are lower than those of the mid vowels, (Connell 2002). According to Connell (2002, p. 102), the gradient nature of IF0 is “to be expected since IF0 is a vowel height phenomenon and perceived vowel height correlates to tongue height”.

IF0 was again found to be gradient in terms of tones such that, according to Connell (ibid) in languages with “more than two tone levels the IF0 should decrease as the tone moves from high to mid to low”.

This study investigated vowel gradient effect of IF0. It sought to investigate how gradient the IF0 is in Ghanaian English as this has been attested in other languages in other studies. The study investigated whether vowels of different heights produced with the same pitch level, show significant F0 differences. It also sought to compare the IF0 of front vowels with those of the back vowels to find the significance of the difference between them as the study by Whalen and Levitt (ibid) indicated no significant differences in the studies reported on.

The objectives of this study were therefore: to investigate what the IF0 values are between Ghanaian English high and low vowels and between the mid and low vowels; to investigate how similar or different the IF0 values of high pitched and low pitched front vowels are from those of the back vowels in Ghanaian English; to test the view that IF0 is neutralized in the lower ends of the F0 range so that the IF0 effect would not be evident in the lower pitches; to compare the IF0 of Ghanaian English with those of American and British English IF0.

In order to achieve the objectives, the following research questions guided the research:

- What are the IF0 sizes of the Ghanaian English high / low; high / mid; and mid / low vowels?
- How similar or different are the F0 and IF0 values of front and back vowels in Ghanaian English?
- How similar or different are the IF0 in high pitch and low pitch parts of the vowels in Ghanaian English?
- How do Ghanaian English IF0 compare with native American and British English IF0?

## **Methodology**

### **Participants and Recording**

The subjects for this study were fifteen males and fifteen females made up of three males and three females each from five different language backgrounds. Participants included six native speakers each of Ga, Dangme, Fantse, Ewe and Dagbani from the Greater Accra, Central, Volta, and Northern regions of Ghana. Their ages ranged between 22 and 30 years. They were all Languages students of the University of Education Winneba purposively sampled for this study. All the participants were Ghanaian speakers of English who have had all their education (from primary to tertiary) in Ghana and had used English language throughout their education. They had neither speech nor hearing defects and could hear, speak, read, and write English well.

The recordings were done in a sound-proof laboratory. For ethical reasons the participants were made to understand that the recording was meant solely for research purposes. The aims of the recording were explained to them and they understood that the exercise was an

academic exercise. They were assured of confidentiality of the recording and they were therefore willing to participate in the exercise.

### **Speech Material**

The test words consisted of vowels in the phonetic environment of “hVd” which were embedded in a carrier sentence of “say \_\_\_\_\_ again, \_\_\_\_\_” whereby the test words were inserted in the blank spaces in the carrier sentence. The signals therefore yielded sentences like ‘say heed again, heed’ for all the test vowels. The “hVd” phonetic environment had been used in most acoustic studies on vowels and had yielded precise descriptions of the sounds investigated, (Peterson & Barney, 1952; Fox 1982; Hillenbrand et al., 1995, Cox 2006). The study recorded vowels /i/, /e/, /ɛ/, /a/, /ɔ/, /o/ and /u/ found in studies of Ghanaian English (Akpanglo-Nartey 2012) for analysis. Table 1 shows the test words used in the study.

**Table 1. Test words**

| <b>Word</b> | <b>Vowel</b> | <b>Word</b> | <b>Vowel</b> |
|-------------|--------------|-------------|--------------|
| heed        | [i]          | hurt        | [ɜ]          |
| Hid         | [ɪ]          | hod         | [ɒ]          |
| hayed       | [e]          | hoard       | [ɔ]          |
| head        | [ɛ]          | hood        | [ʊ]          |
| had         | [æ]          | who’d       | [u]          |
| hard        | [ɑ]          |             |              |
| hut         | [ʌ]          |             |              |

A head-mounted Shure (SM10A) dynamic microphone was positioned about 12cm from the speaker’s lips at an angle of about 45 degrees in order to restrain the speaker’s breath from interfering with the target sounds. The recordings were then subjected to acoustic analysis using PRAAT version 4.3.29.

### **Acoustic Analysis**

The formant tracks were set at a maximum of 5500Hz with window length of 0.005s and dynamic range of 30dB. The pitch range was set at 100Hz for the 15 female speakers and 75Hz for the 15 male speakers. The wave files were annotated to TextGrid and sounds were segmented manually by visually inspecting the waveform and the spectrograms of the sounds. The target sounds were enveloped and measurements of F0, F1, and F2 were generated at the onset, 20%, 35%, 50%, 65%, 80% points through the vowel duration, and the offset of the vowels. The F0, F1, and F2 measurements were based on the automatic formant and pitch trackers on PRAAT.

## **Data Analysis**

The pitch level tracked at the 20% point and the 80% points of the recordings of the vowels showed a fall in pitch on the pitch tracks from the 20% to the 80% points for each of the vowels in the 'hVd' environments. Therefore, IF0 for the vowels were recorded and compared at these two points in order to ascertain any neutralization in the low pitch regions of the vowels. Mean F0 values from onset to offset were also calculated to ascertain the IF0 of the vowel in total. Analysis of variance tests were performed to compare the means of the fundamental frequencies of all the vowels studied. F0 means of high vowels were compared with F0 means of low vowels and also the mid vowels. Also F0 means of the front vowels were compared to those of the back vowels. To determine the IF0 in the high/low dimension, the differences between F0 mean of /i - ɪ/ and /æ/ from the onset to the offset were calculated.

## **Literature Review**

Interest in the interaction between vowel quality and fundamental frequency has yielded many research findings about the phenomenon of intrinsic pitch. Research on the phenomenon indicates that IF0 comes about as a result of an interaction between the laryngeal and supralaryngeal articulators, (Whalen & Levitt, 1995). It is said to be a product of "successful vowel production", (Whalen et al., 1999, p.2) is a language universal (Whalen & Levitt 1995). This phenomenon applies to both the front and back vowels of languages.

A study by Jacewicz and Fox (2015) however has proven that there could be regional variations in the IF0 in American English. Their study identified IF0 differences between high and low vowels in North Carolina were significantly smaller than those of Ohio and Wisconsin. Thus although it is said to be a language universal property, IF0 sizes may not be equal in all languages and varieties of languages.

In a study by Connell (2002), Ibibio, Kunam, Dschang and Mambila showed slight differences in between IF0 measured in semitones. In those languages IF0 were found to be present for most speakers in three of the languages used in those studies both for high and low tones. Mambila on the other hand, did not show significant IF0 according to the study. Speakers showed reduced IF0 values in Mambila than in other languages investigated. In order to provide information about the phenomenon in varieties of languages around the world and to increase understanding of the phenomenon it is necessary to investigate and describe the IF0 of other languages and varieties of language as there could be variations in IF0 across varieties of a language.

One characteristic discovered about IF0 is the disappearance of its effect at the low end of a speaker's F0 range. Connell (2002) in reference to Whalen and Levitt's (1995) reported that the phenomenon is neutralized in low tones. He observed that for high tones in non-tonal languages F0 difference between high and low vowels are observed but vowels in low tones, showed only small differences, if any, between F0 values of the high and low vowels. According to Connell Ladd and Silverman (1984) speculates that low pitch accounts for cases where no IF0 were found. English is a non-tonal language and the vowels produced in some

environments exhibit periods of low and high pitch and therefore the phenomenon of IF0 neutralization could be tested on these vowels in varieties of English as suggested by Ladd and Silverman (1984).

IF0 is said to be gradient in the sense that the F0 of high vowels are higher than those of mid and low vowels and F0 of low vowels are lower than those of the mid vowels, (Whalen & Levitt 1995). As far as the mid vowels are concerned, Fischer-Jorgensen (1990) as cited in Connell (2002) found that only when tense and lax vowels were considered separately in their study on six German speakers did the gradient nature of IF0 occur. On the issue of IF0 being gradient in three tones languages, IF0 in the mid tones are said to be intermediate to those in high and low vowels with neutralization in the low tones. Whalen and Levitt however mentioned that in some of the languages that showed IF0 in the low tones, the vowels may have been produced in the mid region of the speakers' pitch range. This gradient nature of IF0 suggested by Whalen and Levitt (1995) was however not supported by Connell's (2002) study of some African languages in which Kunama and Dschang showed no strong evidence for or against IF0 being gradient in different heights of tone. In that study results showed that the IF0 in mid tones cluster with those in high tones in Kunama while Dschang showed a greater bigger IF0 between the lowest and next lowest tones than found in the other tones. This results by Connell is worth investigating using data from other African languages to find out how tenable the gradient nature of IF0 is.

Relationship between fundamental frequency and vowel height have been attested to by many scholars. These scholars have agreed on the tendency of high vowels to have higher fundamental frequencies than low vowels, (Jacewicz & Fox 2015). A debate on this phenomenon is whether the IF0 pattern automatically comes with vowel production (Whalen & Levitt 1995) or whether it is an enhancement effect deliberately created to enhance vowel contrast in languages, (Kingston & Diehl 1994). According to Jacewicz and Fox (2015), the universality of the phenomenon revealed by Whalen and Levitt's (1995) study supports the phenomenon of IF0 as an automatic aspect of vowel articulation.

The difference between F0 of high and low vowels may be achieved by deducting the F0 of the low vowel /a/ from the mean F0 of the front high vowel /i/ and back high /u/ vowel, (Whalen & Levitt 1995; Gonzales 2009, Jacewicz & Fox 2015; Nkamigbo & Eme 2016). Based on this calculation, Whalen and Levitt (1995) reported an average IF0 of 15.3Hz across all languages.

Previous studies carried out on American English by Fox (1982) as well as Hillenbrand et. al (1995) revealed that the IF0 sizes of male and female calculated by deducting the F0 of low vowels from that of high vowels, showed variations. From the data presented in Hillenbrand et. al (ibid) study, the average F0 for male /i/, /u/ and /a/ were 138Hz, 143Hz and 123Hz respectively. The IF0 for the front vowels yielded 15Hz and for the back vowels, IF0 was 20Hz. For the females, F0 values for /i/, /u/ and /a/ were 227Hz, 235Hz and 215Hz respectively. The IF0 for the female front vowels was 12Hz and for the back vowels IF0 was also 20Hz. The data for the American variety of English showed a bigger IF0 value in the front vowels for the males than was found for the females. In the back vowels however, IF0 was equal for the males and females.

Regarding the front/back dimension of vowels Whalen and Levitt (1995) compared the F0 of the front and back vowels in 31 different languages including English, Dutch, German, Danish, Swedish, French, Italian, Greek, Russian Polish, Japanese among others reported in published studies and realized that F0 differences between /i/ and /u/ was not a significant factor although there were differences in the F0 means of the front and the back vowels of the languages examined. Whalen and Levitt (1995) proposed that while their data may indicate a genuine difference between front and back vowels for English, the results may be more reliable if measurements are carried out for individual languages rather than calculate a mean across different experiments. The study makes a conclusion that there are no universal differences between the F0 of /i/ and /u/.

### Results of data analysis

This section presents the results of data analysis showing measurements of F0 differences between vowels of different heights and pitch. The analysis discusses data for sizes of IF0 for the different height levels of the vowels: high to low, high to mid, and mid to low IF0s for males and females. The section also discusses IF0 differences between front and back vowels and between tense and lax vowels as well. Data for similarities and differences in the IF0 of low pitch and high pitch vowels are also presented in this section. The section also presents results for comparison between IF0 in Ghanaian English and other varieties of English presented in the literature.

### F0 and IF0 sizes for males and female Ghanaian English speakers

**Table 1. F0 and IF0 of male and female English vowels in Hz**

| Vowel     | F0     |       | IF0           | IF0 value |       |
|-----------|--------|-------|---------------|-----------|-------|
|           | Female | Male  |               | Female    | Male  |
| /i/       | 172.6  | 110.7 | /i/ - /æ/     | 7.9       | -1.9  |
| /ɪ/       | 178.9  | 113.1 | /u/ - /ɑ/     | 5.3       | 4.3   |
| /e/       | 170.3  | 122.5 | /i/ - /ɪ/     | -6.3      | -2.4  |
| /ɛ/       | 171.5  | 118.4 | /e/ - /ɛ/     | -1.25     | 4.1   |
| /æ/       | 164.6  | 112.6 | /u/ - /ɔ/     | 5.1       | 2.4   |
| /ɑ/       | 167.2  | 115.1 | /o/ - /ɔ/     | -0.9      | -6.6  |
| /ɒ/       | 157.3  | 123.1 | /ɜ/ - /ʌ/     | 6.6       | -12.1 |
| /ɜ/       | 168.9  | 104.6 | /ɒ/ - /ɑ/     | -10.1     | 8.0   |
| /ʌ/       | 162.3  | 116.7 | /i ɪ/ - /æ/   | 11.1      | -0.7  |
| /o/       | 160.8  | 113.2 | /u ʊ/ - /ɑ/   | 2.8       | 5.5   |
| /ɔ/       | 161.7  | 119.8 | /i u/ - /æ α/ | 6.6       | 2.4   |
| /ʊ/       | 167.8  | 119.4 | /i ɪ/ - /e ε/ | 4.9       | -8.5  |
| /u/       | 172.7  | 121.8 | /u ʊ/ - /o ɔ/ | 8.9       | 4.1   |
| /i/ - /e/ | 2.3    | -11.8 | /e ε/ - /æ/   | 6.3       | 7.8   |
| /i/ - /ε/ | 1.1    | -7.7  | /o ɔ/ - /α ɒ/ | -1.1      | -2.5  |
| /i/ - /æ/ | 8.0    | -1.9  | /u ʊ/ - /α ɒ/ | 7.8       | 1.5   |

|           |      |      |           |      |      |
|-----------|------|------|-----------|------|------|
| /u/ - /o/ | 12.0 | 8.6  | /u/ - /ɒ/ | 15.4 | -1.2 |
| /u/ - /ɔ/ | 11.0 | 2.0  | /e/ - /æ/ | 5.7  | 9.8  |
| /u/ - /ɑ/ | 5.3  | 6.8  | /ɛ/ - /æ/ | 6.9  | 5.8  |
| /o/ - /ɒ/ | 3.4  | -9.9 | /ɔ/ - /ɑ/ | -5.7 | 4.8  |

The means of the fundamental frequency of both males and females are presented in Table 1 and it shows overall means of F0 from onset to offset of the vowels. The results, viewed that way showed IF0 tendencies between high and low vowels. From onset to offset the mean F0 recorded for /i/ was 172.6Hz for the females and 110.7 for the male speakers, while /ɪ/ yielded 178.9Hz for the females and 113.1Hz for the males as shown in Table 1. The data showed that for the females, fundamental frequencies decreased from high to low vowels in the front but in the back vowels the mid and the low vowels were about the same in F0 indicating no reduction in the F0 value of the low vowel.

The males on the other hand, showed higher F0 values for the mid front vowels than for the high front vowels and the F0 value for the low front vowel was not different from that of the high vowels hence no IF0 tendency shown. In the male data, although IF0 was evident between the high and low back vowels, F0 of the high vowels were higher than those of the mid vowels but the mid vowels showed smaller F0s than the low vowels. This indicates a non-uniformity in the IF0 tendency shown in the Ghanaian English data.

The size of IF0 for the front high / low vowels, (/i ɪ/ - /æ/) was 11.1Hz for the females and -0.7Hz for the males. When the tense and lax front vowels were put together in ascertaining the IF0, the female data showed a significant IF0 but the male data showed a negative IF0 which is a neutralization of IF0. When the front and back high vowels were averaged to calculate the IF0 both male and female data showed positive values for the front and the back vowels.

When the tense and lax front vowels were considered separately there were reduced IF0 sizes recorded for both males and females though the males still recorded negative IF0. IF0 of the high tense and the low front vowels recorded was 7.9Hz for the females and -1.9Hz for the males. Therefore, whether the tense and lax vowels are used or the tense vowel only is used in calculating the IF0, the males showed a neutralization of the IF0 in the front vowels.

Putting the front vowels and back vowels together in ascertaining the IF0 (i.e. /i u/ - /æ α/) resulted in the IF0 of 6.6Hz for the female participants and 2.4Hz for the male participants. In all of these, the female data showed higher IF0 sizes than their male counterparts who recorded neutralization of IF0 in some cases.

### **IF0 for the mid vowels**

IF0 differences calculated for the high and mid front tense and lax vowels (/i ɪ/ - /e ε/), yielded 4.9Hz for the females and -8.5Hz for the males. Thus a lower IF0 size as compared with the values obtained for IF0 of the high front tense and lax vowels and the low front vowel (/i ɪ/ - /æ/). In the back vowels, IF0 of the high and the mid (/u ʊ/ - /o ɔ/) yielded 8.9Hz for the females and 4.1Hz for the males. This shows a higher value than the value obtained for

the high and low back vowels (/u ʊ/ - /ɑ ɒ/) which yielded 7.8Hz for females and 1.5Hz for males. Therefore, the results indicated that when the tense and lax vowels were put together, IF0 between the high and mid vowels was not gradient as proposed in the study of Whalen and Levitt (ibid). This results corresponds with that of Connell (ibid) which found that IF0 was not uniformly gradient in some of the languages investigated.

When the IF0 of mid vowels was calculated separately for tense and lax vowels, the front vowels for the females showed IF0 of high/mid vowels lower (/i/ - /e/= 2.3Hz; /i/ - /ε/= 1.1Hz) than that of the high and low IF0 (/i/ - /æ/= 8.0Hz). For the males, the high/mid vowels showed similar pattern to that of the female (/i/ - /e/= -11.8Hz; /i/ - /ε/= -7.7Hz; /i/ - /æ/= 8.0Hz). The IF0 for mid and low vowels (/e/ - /æ/) were 5.7Hz for the females and 9.8Hz for the males which showed higher IF0 than the values for the high/mid IF0. Thus the gradient nature of IF0 was absent in the front tense vowels for both the males and the females as the mid to low vowel IF0 was bigger than that for the high to mid vowels.

In the back vowels IF0 from high to mid for the females was 12.0Hz and that for the males was 8.6Hz while IF0 from mid to low 3.4Hz and -9.9Hz for females and males respectively. The back vowels therefore showed IF0 as being gradient as the high to mid value was bigger than the value from mid to high for both the males and the females.

#### **IF0 sizes of front and back vowels of males and females**

IF0 calculated for the front vowels (/i/ - /æ/) yielded a negative value of -1.9Hz in the male data but a positive of 7.9Hz in the female data. In the IF0 for the back vowels (/u/ - /ɑ/) the female IF0 size of 5.3Hz which is lower than the value obtained in the front vowels but in the data for the males, there was a higher IF0 value of 4.3Hz in the back vowels in contrast to the -1.9Hz recorded for the front vowels.

Therefore, in the current data, the average F0 values calculated with the tense vowels, showed IF0 tendencies in both the front and back vowels for females. This tendency was however, showed only in the back vowels for the males who showed a neutralization of IF0 in the front vowels. The relationship between IF0 of the front high vowels and the back high tense vowels was thus not uniform for males and females in this study. While the front high tense showed IF0 higher than that of the back high tense vowel for the females, the males showed a higher size for the back vowels than the front vowels.

A similar trend was seen when the tense and lax high vowels were put together (/i ɪ/ - /æ/) in ascertaining the IF0. In that, the female data indicated 11.1Hz for the front vowels and 7.8Hz (/u ʊ/ - /ɑ ɒ/) for the back vowels while the male data showed -0.7Hz for the front vowels but 1.5Hz for the back vowels.

#### **IF0 from onset to offset in the Back vowels**

There were IF0 tendencies manifested in the back vowels of both male and female speakers but these differences in the F0 were not as profound as found in the front vowels. Shown in



Table 2 are the IF0 of the back vowels. For the female speakers, IF0 at the onset is largest for all the different heights: high, mid, and low however, the F0 difference between /u/ and /ʊ/ was bigger than the F0 difference between /u/ and /ɑ/ from the onset to 35%. From 50% to the 80% IF0 was smaller between /u/ and /ʊ/ than between /u/ and /ɑ/.

The mean IF0 between /i/ - /æ/ for the females, shown in Table 3, is 8Hz while that of /u/ - /ɑ/ is 5.3Hz. The average F0 for the high front vowels (i/ɪ - /æ/) on the other hand yielded IF0 of 11Hz while the average back high vowels (u/ʊ - /ɑ/) yield IF0 of 3Hz. For the males, IF0 between /i/ - /æ/ yielded -2Hz and for /u/ - /ɑ/ IF0 was 4.3Hz. The male average F0 for the high front vowels yielded IF0 of -0.7Hz while the average back high vowels yield IF0 of 5.5Hz.

The data showed an indication that although IF0 is recognized in the back vowels the size of the difference is not as big as it is for the front vowels especially for the females. This however, does not work out that way for the males in whose data the IF0 for the front vowels is a negative value while that for the back vowels is a positive value. Thus IF0 was not consistently higher in the front vowels than the back vowels as it was in Nkamigbo and Eme (2016) which reported that front vowels have higher IF0 than back vowels in Igbo.

The average F0 for the high front/back vowels (/i/u/ - /æ/a/) yielded IF0 of 6.7Hz for the females and 2.4Hz for the males.

**Table 2: Female and Male F0 values from onset to offset of vowels**

| female | Front High |     | Front Mid |     | Front low | Central Mid |     | Back Mid |     | Back High |     | Back low |     | pitchrange<br>Max-Min |
|--------|------------|-----|-----------|-----|-----------|-------------|-----|----------|-----|-----------|-----|----------|-----|-----------------------|
|        | /i/        | /ɪ/ | /e/       | /ɛ/ | /æ/       | /ɜ/         | /ʌ/ | /o/      | /ɔ/ | /u/       | /ʊ/ | /ɑ/      | /ɒ/ |                       |
| onset  | 204        | 199 | 203       | 198 | 188       | 191         | 181 | 185      | 180 | 197       | 184 | 184      | 188 | 20                    |
| 20%    | 196        | 199 | 195       | 189 | 183       | 183         | 174 | 177      | 176 | 189       | 181 | 174      | 184 | 25                    |
| 35%    | 186        | 192 | 183       | 181 | 177       | 177         | 170 | 172      | 171 | 182       | 177 | 165      | 179 | 27                    |
| 50%    | 175        | 184 | 171       | 172 | 166       | 169         | 165 | 164      | 164 | 174       | 171 | 158      | 168 | 26                    |
| 65%    | 159        | 172 | 155       | 161 | 157       | 161         | 160 | 153      | 155 | 165       | 163 | 148      | 158 | 24                    |
| 80%    | 148        | 156 | 146       | 155 | 144       | 155         | 148 | 141      | 143 | 156       | 155 | 138      | 147 | 19                    |
| offset | 140        | 150 | 140       | 146 | 138       | 147         | 139 | 135      | 144 | 147       | 143 | 135      | 148 | 15                    |
| Mean   | 173        | 179 | 170       | 172 | 165       | 169         | 162 | 161      | 162 | 173       | 168 | 157      | 167 | 22                    |
| Male   | Front High |     | Front Mid |     | Front low | Central Mid |     | Back Mid |     | Back High |     | Back Low |     | pitchrange<br>Max-Min |
|        | /i/        | /ɪ/ | /e/       | /ɛ/ | /æ/       | /ɜ/         | /ʌ/ | /o/      | /ɔ/ | /u/       | /ʊ/ | /ɑ/      | /ɒ/ |                       |
| onset  | 131        | 132 | 135       | 134 | 124       | 115         | 128 | 119      | 128 | 131       | 126 | 131      | 129 | 19                    |
| 20%    | 127        | 127 | 134       | 130 | 121       | 114         | 123 | 117      | 126 | 128       | 124 | 129      | 125 | 20                    |
| 35%    | 118        | 117 | 126       | 122 | 117       | 110         | 118 | 116      | 123 | 124       | 123 | 126      | 119 | 17                    |
| 50%    | 106        | 111 | 120       | 117 | 113       | 105         | 132 | 114      | 120 | 122       | 120 | 122      | 112 | 20                    |
| 65%    | 100        | 106 | 116       | 114 | 107       | 100         | 108 | 111      | 117 | 119       | 117 | 120      | 110 | 20                    |
| 80%    | 98         | 101 | 116       | 107 | 104       | 95          | 105 | 109      | 113 | 116       | 113 | 117      | 107 | 23                    |
| offset | 95         | 99  | 111       | 105 | 102       | 92          | 104 | 108      | 112 | 113       | 113 | 116      | 104 | 20                    |
| Mean   | 111        | 113 | 122       | 118 | 113       | 105         | 117 | 113      | 120 | 122       | 119 | 123      | 115 | 12                    |

### **F0 and IF0 from vowel onset to offset**

The data as presented in Table 2 showed a steady reduction of the F0 from the onset to the 50% point of the vowel. This part of the vowel was the higher pitch part and the F0 showed that. The reduction in F0 was also seen in the lower pitch portions (from the 65% to offset). Thus whether the vowels were produced in high pitch or low pitch, there was a steady reduction in the F0 from the onset to the offset of the vowel. Figure 1 is a graphical representation of the fundamental frequencies from onset to offset of the vowels in the target words used.

F0 for the high vowel / i / is consistently higher than F0 of / æ / especially in the initial parts of the vowel as shown in Table 2. Towards the offset of these vowels however, the F0 of / i / in the female data reduced to about the F0 value for / æ / while the male data showed a higher F0 value for the low vowel / æ / than the high vowel / i /. This showed that there was much more reduction of the F0 for the high vowel than there was for the low vowel. This finding is consistent with the universal aspect of IF0 being a physiological feature (Van Hoof and Verhoeven (2011) cited in Jacewicz & Fox 2015).

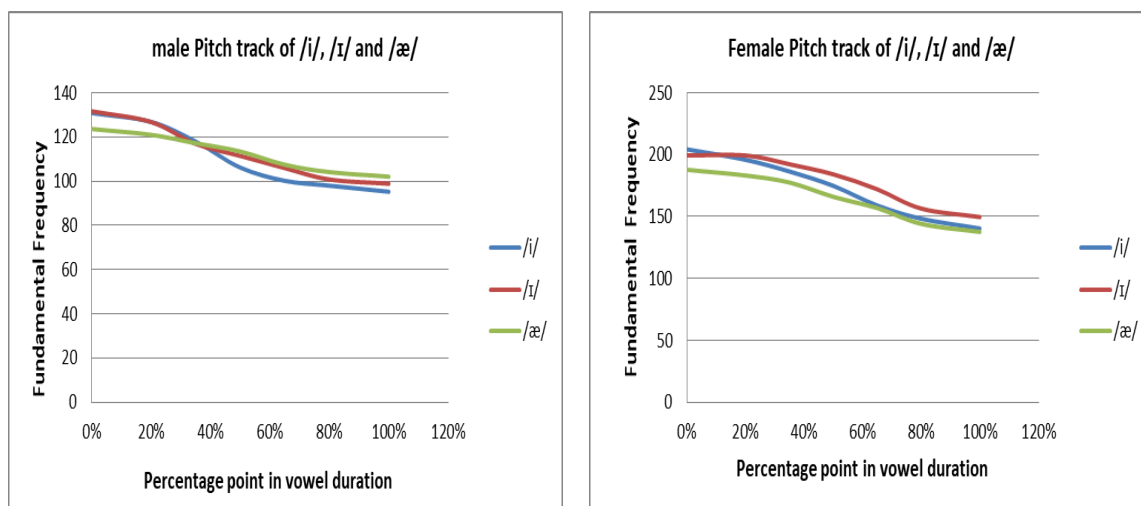


Figure 1: Male and female pitch tracks

In the female data, the IF0 sizes (calculated by deducting the F0 of the low vowel from that of the high vowel) of the front vowels showed noteworthy variations from the onset to the offset of the vowels. The IF0 between the onset and 20% showed a significant difference, [F (1, 21) = 514, p<0.000]. The data as shown in Table 3 indicated that at the onset, IF0 was 16.5 Hz which reduced by about 4Hz in the 20% point of the vowels. There was another reduction of 4Hz between the 20% and 35%. Thus the data indicated a steady drop in the IF0. Between the 35% and 50% however there was no variation in IF0, [F (1, 21) = 514, p<0.100]. The data indicated 8.9Hz IF0 at the 35% point and 8.8Hz IF0 at the 50% point.

Table 3: Female and Male IF0 of front and back vowels

| female | IF0 in Front<br>/i/ - /æ/ | IF0 in back<br>/u/ - /ɑ/ | IF0 in front high<br>/i/ - /ɪ/ | IF0 in fron mid<br>/e/ - /ɛ/ | IF0 in back high<br>/u/ - /ʊ/ | IF0 in back mid<br>/o/ - /ɔ/ | IF0 in central mid<br>/ɜ/ - /ʌ/ | IF0 in Back Low<br>/ɒ/ - /ɑ/ |
|--------|---------------------------|--------------------------|--------------------------------|------------------------------|-------------------------------|------------------------------|---------------------------------|------------------------------|
| onset  | 16.5                      | 8.5                      | 5.0                            | 5.5                          | 12.3                          | 4.3                          | 10.0                            | -4.0                         |
| 20%    | 12.7                      | 4.1                      | -3.5                           | 5.9                          | 7.8                           | 1.7                          | 9.3                             | -10.3                        |
| 35%    | 8.9                       | 3.1                      | -5.8                           | 1.8                          | 5.5                           | 0.3                          | 6.8                             | -14.0                        |
| 50%    | 8.8                       | 6.4                      | -9.3                           | -1.3                         | 3.4                           | -0.7                         | 3.8                             | -9.9                         |
| 65%    | 2.1                       | 7.3                      | -13.1                          | -6.1                         | 1.7                           | -1.8                         | 1.5                             | -9.8                         |
| 80%    | 4.2                       | 9.1                      | -8.2                           | -8.6                         | 1.1                           | -1.9                         | 6.8                             | -9.0                         |
| offset | 2.8                       | -1.3                     | -9.3                           | -6.0                         | 3.8                           | -8.5                         | 8.3                             | -13.8                        |
| Mean   | 8.0                       | 5.3                      | -6.3                           | -1.3                         | 5.1                           | -1.0                         | 6.6                             | -10.1                        |
| Male   | IF0 in Front<br>/i/ - /æ/ | IF0 in back<br>/u/ - /ɑ/ | IF0 in front high<br>/i/ - /ɪ/ | IF0 in fron mid<br>/e/ - /ɛ/ | IF0 in back high<br>/u/ - /ʊ/ | IF0 in back mid<br>/o/ - /ɔ/ | IF0 in central mid<br>/ɜ/ - /ʌ/ | IF0 in Back Low<br>/ɒ/ - /ɑ/ |
| onset  | 7                         | -3                       | -0.8                           | 0.8                          | 4.6                           | -8.6                         | -12.2                           | 2.4                          |
| 20%    | 6                         | -1                       | 0.1                            | 4.5                          | 4.0                           | -9.1                         | -8.5                            | 4.2                          |
| 35%    | 1                         | 4                        | 1.1                            | 4.1                          | 1.3                           | -7.5                         | -8.7                            | 7.2                          |
| 50%    | -7                        | 7                        | -5.3                           | 2.5                          | 2.5                           | -6.4                         | -26.4                           | 9.8                          |
| 65%    | -7                        | 7                        | -5.7                           | 2.1                          | 2.3                           | -6.5                         | -7.7                            | 9.7                          |
| 80%    | -6                        | 7                        | -2.8                           | 8.5                          | 2.2                           | -4.7                         | -10.1                           | 10.7                         |
| offset | -7                        | 9                        | -3.6                           | 6.0                          | 0.2                           | -3.8                         | -11.2                           | 12.0                         |
| Mean   | -2                        | 4                        | -2.4                           | 4.1                          | 2.4                           | -6.6                         | -12.1                           | 8.0                          |

Between the 50% and 65% points IF0 reduced by about 6Hz. By the time of the offset, IF0 is only 2.8Hz which is about 14Hz lower than IF0 at the onset. This indicates that in the first half of the vowel which was pronounced with a relatively higher pitch, IF0 was higher but in the last 40% of the duration, IF0 was reduced considerably. Therefore, IF0 was not negative in the lower frequencies of the female data, it was reduced drastically.

The male data showed similar tendencies with the lower pitch range in the last 40% showing negative IF0. Thus the male data showed evidence of IF0 neutralization in lower pitch especially for the front vowels. In both the male and female data, IF0 was relatively higher in the onset through the 40% of the duration but lower towards the offset of the vowels. This confirms the view point that IF0 decreases as pitch is reduced. Figure 1 shows average pitch tracks for respondents.

The data showed larger IF0 sizes in the female data than in the male data. The first 20% of the vowels showed an average IF0 (/i/ - /æ/) of 14.6Hz for the females while the male data showed an average of 6.5Hz of IF0.

A careful look at the data in Table 2 shows that for the female speakers, mean F0 for /i/ and /ɪ/ yielded 176Hz while that for the mid vowels yielded 171Hz and for the low vowels IF0 was 165Hz. The male speakers showed mean F0 for /i/ and /ɪ/ of 112Hz while that for the mid vowels yielded 120Hz and for the low vowels F0 was 113Hz. In considering high, mid and low dimensions of the vowels for the females, F0 was seen to decrease from the high vowel to the low vowel therefore the value for the mid vowels falls between that for the high and low vowels. For the male speakers however, the mid vowels exhibited higher F0 values than the high vowels.

The difference in F0 between high (i/ɪ) and mid vowels (e/ɛ) for the females was 5Hz while difference in F0 between the mid and the low vowels was 6Hz. For the male speakers, the difference in F0 between high and mid vowels was -8Hz and difference in F0 between the mid and the low vowels was 7Hz. The difference in F0 between /i/ɪ/ and /æ/ yielded 11Hz and between /e/ɛ/ and /æ/ yielded 6Hz for the females while the difference in F0 between /i/ɪ/ and /æ/ was -1Hz and between /e/ɛ/ and /æ/ yielded 7Hz for the males. These values show that IF0 is higher for high / low vowels and lower for mid / low vowels for the females but not for the males whose data showed higher mid / low IF0 values instead.

### **IF0 in tense and lax vowels**

In the tense/lax dimensions, it was realized in the female mean IF0 values that there was neutralization in the high front vowels, the mid front vowels, back mid and low back vowels. This was because the lax vowels exhibited higher F0 values than the tense vowels. Therefore, the phenomena of IF0 did not materialize as far as tense vs. lax vowels in the data. It disagrees with the idea that the higher the vowel the higher the F0, (Whalen & Levitt 1995). The back high and central mid vowels however showed positive IF0 means of 5.1Hz and 6.6Hz respectively. This implies that in the tense/lax dimension of the vowels, IF0 is neutralized for some of the pairs but not for other pair of vowels.

The male values on the other hand showed neutralization in the front high pair, back mid pair and the central pair of vowels, but the front mid, back high and the back low pairs of vowels showed positive IF0.

In the female data, IF0 between the front high vowels and front mid vowels is 2Hz (145Hz – 143Hz) and between the mid vowels and the low vowel in front IF0 is 5Hz (143Hz - 138Hz). The IF0 between the high back vowels and the back mid vowels is 5Hz (145Hz – 140Hz) and between the mid back and low back vowels IF0 is -2Hz (140Hz – 142Hz). In the front dimension therefore IF0 was lower between high and mid vowels but higher between mid and low while in the back dimension IF0 was higher between high and low vowels than it was between mid and low vowels.

IF0 between the front high vowels and front mid vowels for the males is -8 Hz (112Hz – 120Hz) and between the mid vowels and the low vowel in front IF0 is 7Hz (120Hz - 113Hz). The IF0 between the high back vowels and the back mid vowels is 4Hz (121Hz – 117Hz) and between the mid back and low back vowels IF0 is -2Hz (117Hz – 119Hz). IF0 from high to mid in the male data is therefore higher than IF0 from mid to low in both the front and the back vowels. This data therefore does not present a uniform gradient of IF0 from high to low vowels by males and females.

### **Comparison of IF0 of Ghanaian English Vowels and American English vowels**

The IF0 values obtained for the Ghanaian variety of English indicated 8Hz for female front vowels and -2Hz for the male front vowels. The back vowels showed IF0 of 5.3Hz for the females and 4.3Hz for the males. Compared with the results Hillenbrand et. al. (1995), Ghanaian English IF0 seem to be smaller for both males and females. While the American English data had 15Hz for males and 12Hz for females, the Ghanaian variety had 8Hz for females and even a neutralization of IF0 for the male front vowels. The back vowels just like the front vowels, showed reduced IF0s for the Ghanaian variety.

### **Conclusion**

Based on the fundamental frequencies (F0) of the vowels, it is concluded that as is found in other varieties of English in studies identified by (Whalen & Levitt 1995), intrinsic fundamental frequency (IF0) is present in Ghanaian English. This conclusion is arrived at because IF0 calculated for the high front and back vowels and the low front and back vowels yielded positive values for both male and female participants in the study.

A careful look at the data however revealed some non-uniformity of the phenomenon in the front and back dimensions especially when calculations were made without putting the front and back vowels together. The data showed that for the females, fundamental frequencies decreased from high to low vowels in the front but in the back vowels the mid and the low vowels were about the same in F0 indicating no reduction in the F0 value of the low vowel. Bigger F0 values for the mid front vowels than for the high front vowels were recorded for the males. Also, the F0 value for the low front vowel was not different from that of the high

front vowels. This means that the male data showed no IF0 tendency. Again, although IF0 was evident between the high and low back vowels, the mid vowels showed smaller F0 values than the low vowels. This indicates a non-uniformity in the IF0 tendency shown in the Ghanaian English data.

The size of IF0 for the front high / low vowels, (/i ɪ / - /æ /) was 11.1Hz for the females and -0.7Hz for the males. When the tense and lax front vowels were put together in ascertaining the IF0, the female data showed a significant IF0 but the male data showed a negative IF0 which is a neutralization of IF0. Therefore, whether the tense and lax vowels are used or the tense vowel only was used in calculating the IF0, the males showed a neutralization of the IF0 in the front vowels. When the front and back high vowels were averaged to calculate the IF0 both male and female data showed positive values for the front and the back vowels. The tense and lax front vowels considered separately yielded reduced IF0 sizes recorded for both males and females though the males still recorded negative IF0. The value of IF0 of the high tense and the low front vowels recorded was 7.9Hz for the females and -1.9Hz for the males. Putting the front vowels and back vowels together in ascertaining the IF0 (i.e. /i u/ - /æ α/) resulted in the IF0 of 6.6Hz for the female participants and 2.4Hz for the male participants. In all of these, the female data showed higher IF0 sizes than their male counterparts who recorded neutralization of IF0 in some cases.

The IF0 differences calculated for the high front tense and lax vowels and the mid front tense and lax vowels (/i ɪ / - /e ε /), yielded 4.9Hz for the females and -8.5Hz for the males. Thus a lower IF0 size as compared with the values obtained for IF0 of the high front tense and lax vowels and the low front vowel (/i ɪ / - /æ /).

In the back vowels, IF0 of the high and the mid (/u ʊ / - /o ɔ /) yielded 8.9Hz for the females and 4.1Hz for the males. This shows a higher value than the value obtained for the high and low back vowels (/u ʊ / - /ɑ ɒ /) which yielded 7.8Hz for females and 1.5Hz for males. Therefore, in the results obtained, there is no indication of gradient IF0 when the tense and lax vowels are put together in the calculation of IF0 as proposed in the study of Whalen and Levitt (ibid). The results of this study corresponds with that of Connell (ibid) which found that IF0 was not uniformly gradient in some of the languages investigated.

When the IF0 of mid vowels were calculated separately for tense and lax vowels, the front vowels for the females showed lower IF0 values of high/mid vowels (/i / - /e/= 2.3Hz; /i / - /ε / = 1.1Hz) than that of the high / low IF0 (/i / - /æ /= 8.0Hz). For the males, the high/mid vowels showed similar pattern to that of the female (/i / - /e/= -11.8Hz; /i / - /ε / = -7.7Hz; /i / - /æ /= 8.0Hz). The IF0 for mid and low vowels (/e / - /æ /) were 5.7Hz for the females and 9.8Hz for the males which showed higher IF0 than the values for the high/mid IF0. Thus the gradient nature of IF0 was absent in the front tense vowels for both the males and the females as the mid / low vowel IF0 value was bigger than that for the high / mid vowels.

The phenomenon of a gradient F0 through the different heights, is evident in the front vowels of female participants but in their back vowels, the F0 did not decrease from the mid to the low vowels that is, F0 of the mid front vowels were not higher than the low vowel F0. In the male data, the mid front vowels showed bigger F0 values than the values for the high front vowels which were not very different from the value for the low front vowel. This showed a

contrary situation to the gradient IF0 phenomenon. In the back vowels for the males, just like in the female data, F0 for the mid vowels were lower than the F0 for the low vowel. The phenomenon of gradient IF0 therefore was not supported by the data on the back vowels of Ghanaian English in the study. The front vowels for the female participants however, showed gradient IF0 whereby the F0 of the mid vowels were in between the F0 of the high and the low vowels.

The IF0 calculated with the mean F0s of / i /, / u / and / æ /, / α / (/i/u – æ/α/), was found to be 6.7Hz for the female speakers and 2.4Hz for the male speakers. These values were far less than the IF0 values proposed by Whalen and Levitt (ibid) which proposed an average of 15.3Hz IF0. This suggests that generalizations of this kind need to take into consideration many more languages than was used by Whalen and Levitt.

The results on American English by Hillenbrand et. al. (1995), were quite different from results obtained in Ghanaian English. IF0 in Ghanaian English were smaller for both males and females. While the American English data had 15Hz for males and 12Hz for females, the Ghanaian variety had 8Hz for females and even a neutralization of IF0 for the male front vowels. The back vowels just like the front vowels, showed reduced IF0s for the Ghanaian variety.

Compared to the results of IF0 investigation on American English by Jacewicz and Fox (2015) which reported IF0 of 5.6Hz for North Carolina, 16.3Hz for Ohio and 20.5Hz for Wisconsin females, the IF0 for Ghanaian English female speakers was close to that of the North Carolina speakers but very different from those of Ohio and Wisconsin female speakers. It is important therefore to note that different varieties of a language would exhibit different IF0 sizes making the phenomenon a language dependent one. This supports the argument that IF0 is a process of enhancing the contrast with the vowel systems of languages.

In the front dimension IF0 between high and low vowels was realized to be lower than IF0 between mid and low vowels in the front vowels while in the back dimension IF0 is higher between high and low than it is between mid and low vowels in the female data. In the male data however, IF0 value between the high and mid vowels is higher than IF0 value between the mid and low vowels in both the front and the back vowels. This data therefore does not present a uniform gradient of IF0 from high to low vowels by males and females.

It came clear in the study that IF0 was not consistently higher in the front vowels than the back vowels as it was in the study of Nkamigbo and Eme (2016) which reported that front vowels had higher IF0 than back vowels in Igbo. The Study showed that for the female speakers of Ghanaian English, the lax vowels exhibited higher F0 values than the tense vowels disagreeing with the concept of higher vowels having bigger F0, (Whalen & Levitt 1995) in the tense/lax dimension of the vowels. Thus there was neutralization of the IF0 as far as tense / lax is concerned in the high front vowels, the mid front vowels, back mid and low back vowels. It can be concluded therefore that the tendency of IF0 does not apply to tense and lax vowels within the same vowel height.

Findings of studies on the F0 norms in languages are necessary to ultimately generate F0 norms for international speakers and for clinical purposes. The study of the Ghanaian English

IF0 throws some light on the nature of IF0 in English by Ghanaian English speakers. The results contribute knowledge on the voice of the Ghanaian English bilingual speaker.

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