Wavelength and fundamental frequency as determinants of type of intonation

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Abstract
In this study, attempts have been made to use wavelength and fundamental frequency as cues to the determination of type of intonation. Twenty five pairs of utterances were produced by native speakers of English and Ika Igbo. These were produced with various tunes and their wavelengths and fundamental frequencies were calculated using the praat software. Though generally, the High Rise intonation showed a consistent relationship between the wavelengths and the Fos, there were much inconsistencies in the other intonation types – Low Rise, Rise Fall and Fall Rise. Hence using Fo and wavelength relationship in determining type of intonation may not be reliable.

1.0 Introduction

Ika Igbo manifests both tone and intonation. Ika and English have similar intonation patterns (Uguru, 2010). Hence in this study, the FOs and wavelengths of their utterances are studied and compared to establish if their intonation patterns (type of intonation) can be determined through FO and wavelength values. Fundamental frequency (FO) is a major acoustic correlate of intonation. It is measured in hertz. The frequency of a sound has to do with the sound waves that pass a given point in a second.

That is, the number of sound waves that pass a given point per second. When we refer to fundamental frequency we mean the fundamental frequency of vocal cords vibration (Fry, 1979). Ladefoged (1968:41) explains that the phonetic correlate of intonation is the rate of vibration of the vocal cords that is, frequency. He shows that there can be a deliberate slackening of the tension of the vocal cords to reduce pitch. According to him, pitch normally increases whenever the tongue is raised for the production of front vowels, [i] and [u]. Thus syllables containing these vowels are usually slightly higher than others.

During speech, fundamental frequency varies and as it varies, various intonation patterns are produced. The adjustment made in the mass, length and tension of the vocal cords leads to variations in the frequency of their vibrations. The adjustment is made in correspondence to the intonation pattern the speaker wants to convey (Fry, 1979: 69). Lieberman (1967: 7) explains that to vary the fundamental frequency, both the muscles of the larynx and those of the sublaryngeal system are adjusted.

The FO has a mathematical relationship with the harmonics (Fry, 1979: 46). Harmonics or overtones are multiples of fundamental frequency. They refer to surplus amounts of energy generated by a vibration. In the production of a tone, the vibration of the vocal cords may be so much, resulting in extra frequencies in addition to the fundamental one. The harmonics are numbered consecutively upwards with the one immediately above the FO being the second harmonic. The fundamental frequency serves as the starting point of the consecutive numbering. To get the frequencies of the harmonics, the frequency (number or value) of the FO is multiplied by successive whole numbers (Fry 1979: 46). Thus if the FO is 200 Hz, the second harmonic would be 400 Hz,

the third one would be 600 Hz, the fourth one would be 800 et cetera.

The wavelength is the distance between two successive wave crests. While the FO has a full wavelength, the second harmonic has wavelengths that are half the length of that of the FO. The wavelengths of the third harmonic are thrice shorter than that of the FO. The reason behind this is that subsequent harmonics have higher frequencies and consequently, shorter wavelengths. Lower frequencies have longer wavelengths. This is illustrated below.

F_0
Fundamental Frequency

F_1
Second harmonic

F2
Third harmonic

F_3
Fourth harmonic

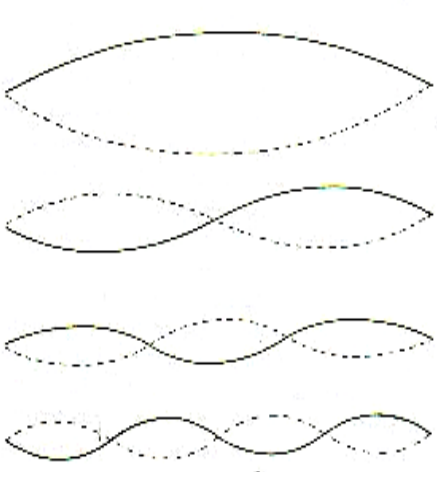

Fig.(i) Different modes of vibration and their resulting wavelengths

Fry (1979: 45) with modifications

The frequency at which the vocal cords vibrate is determined by the tension of the vocal cords and the magnitude of the subglottal air pressure (Muller, 1848; Van den Berg, 1960; Ladefoged, 1961; and Soron and Lieberman, 1963). Thus research has shown that fundamental frequency increases with increased vocal effort.
Stibbard (1996) has been able to use visual display of FO to teach English intonation to non native speakers of English. By imitating the visual display of the FO of a model's pronunciation, the learners were able to learn the vocal range (in hertz) that is appropriate for a particular intonation. Any shift from the vocal range resulted in the production of a wrong intonation.

Uguru (2013) also shows that FO can be used as a cue to type of intonation. She observes that rising tunes (high tunes) have high FOs while falling tunes have low FOs. The study was carried out with three rising intonation – High Rise, Low Rise and Fall Rise, shows that the utterances with High Rise had higher FOs than the other two types of intonation – Low Rise and Fall Rise. Based on the foregoing, this study sets out to discover if both the wavelength and the FO can be used as cues to intonation types. That is, can one determine type of intonation by observing the relationship between FO and wavelength of utterances? This question is answered in the subsequent sections of this study.

2.0 Materials and methods

Twenty- five sets of utterances for both Ika and English were used for the study. The test utterances, together with their various tunes, appear below.

English Test Utterances	**Ika Test Utterances** **Basic tones of words are shown**

	below the syllables
Low Rise (wh questions for encouraging**,** wondering et cetera), , **I.** /**Where? (emphasis)**	**Low Rise** (casual question) /We **– *they*** **H**
II. /**When did you, come?**	We edi/koꜜ? – ***Won't they endure?*** **H H L L**
wh question used as polite and routine question) III. Who are /you?	**Casual question** We leꜜ/yuꜜ? ***They and you?*** **H L H**
(Yes/no question showing indifference and scepticism IV. Can you /come?	**Casual question** Nkə yu a/koꜜ? - ***Would you have shaved?*** **H L L L H**
Statements showing scepticism or caution in English **V.** /**Some of us do**	Statements showing scepticism or caution in Ika /I some we …***If you keep following*** **H L H H** them… (threat and warning)

VI. It is al ˎ right.	O̩ si̩ ni̩ o̩ ˎ ria̩ … - ***If she says he is not in***. **H H H H HH** (threat and warning)
VII. ˎ **No (encouraging)** **VIII.** ˎ **Yes (encouraging)**	ˎ **nu̩ –** *hear* **(emphasis)** **H** ˎ **Ya – (you) emphasis** **H**
HR Questions for seeking repetition and showing surprise in English **IX**. ˊWhere?	**HR Questions for seeking repetition and showing surprise in Ika** ˊ**We? –*They*?** **H**
X. When did you ˊcome?	We eˊdiko̩? – ***won't they endure***? **H HL L**
XI. ˊ **What's the time?**	KƏ wu̩ ˊtaani̩ ? – ***(did you say) what day is today***? **H L HLL**
XII. ˊ **Who?** ˊ **Murray?**	ˊ**hu̩ ahu̩?** ˊ**mari̩? –** *that one? Know?* **HH H H H**

XIII. $^{/}$It is?	**I $^{/}$si̤? –** *pardon? /come again***.** **L L**
XIV. $^{/}$No (surprise)	**(ni̤ m) $^{/}$nṳ -** *hear* **(surprise)** **H**
XV. $^{/}$Yes (surprise)	$^{/}$Ya? – ***she /it?*** (surprise) **H**

FR Questions for showing forcefulness, encouragement and prompting in English	**FR Questions for showing forcefulness, encouragement and prompting in Ika**
XVI. ^{V}Where?	^{V}We ? – ***You mean them?*** **H**
XVII. ^{V}Who are you?	Hṳ we ^{V}yu?–***The one who took you?*** **H H H**
XVIII. You ^{V}did	yu^{V}zi – ***You sent?*** **H H**
XIX. ^{V}Mary (friendliness)	mme̤ ^{V}ri-***Scoop?*** **(**question and surprise) **L H L**

Statement showing scepticism and nonchalance in English	**Statement showing scepticism and nonchalance in Ika**
XX. ^{V}no (scepticism/ nonchalance)	**(nị̣ m) … ^{V}nụ̣ -*hear*?(disbelief)** **H**
XXI. ^{V}Yes (scepticism)	^{V}Ya? – ***he /she /it?*** (surprise and disgust) **H**
(RF) Expression of Disgust and Emphasis in English **XXII. This is ^mine.**	**(RF) Expression of Disgust and Emphasis in Ika** Ishi ^manya n**! -*The stench of this*** **H L M M L** ***drink!***
XXIII. Who are ^you?	Yụ kẹ̣ m^zu**? –*Are you the one I met /am*** **H LH L *meeting?***
XXIV. ^Really.	^Ishii**? –*Six?*** **L HL**
XXV. ^Good morning.	^O bu ọ̣nyị? –***Does it cause dysentery?*** **L HL L (disbelief)**

Two adult male native speakers – one for English and another for Ika were selected. Gimson's recording (which has an accurate use of English intonation) served as the native English speaker since it was not easy to get an English native speaker in our immediate environment. The Ika speaker is well versed in the use of Ika intonation being a native speaker who has spent a lot of time in

Umunede. The tape recordings (speech signals) of the two informants (male adults) were recorded with a microphone, played into the computer and digitized mainly at 8000 KHz frequencies.

The study centred on the use of four types of intonation– High Rise, Low Rise, Fall Rise and Rise Fall in both languages. Henceforth these tunes may be referred to as HR, LR, FR and RF. The wavelengths of the four intonation patterns (that is, the utterances in which they were used) in the two languages were measured based on the waveforms of the informants' productions. Also the mean FO values of the utterances were calculated. Though the work is an empirical work, requiring no theoretical framework, it sets out to prove or disprove the place or resonance theory which states that the louder a sound (frequency) the faster the rate of firing (wavelength) (Fry, 1979).

3.0 Analysis

The wavelengths of the intonation patterns

The wavelength of a sound is determined by the velocity (speed) of the sound as well as its frequency. Henning and Allard (2009) show that wavelength depends on the speed and frequency of a sound. For high frequencies, the wavelength is small; for low frequencies, the wavelength is large. The time interval between successive waves is determined by the frequency of the vibration; from the velocity of the sound we can calculate what distance will be covered in this time (Fry, 1979:36). Velocity determines the length of the wavelength of a given frequency. The velocity of a sound wave is constant – about 340 m/s (metres per second) (Fry, 1979: 33). The formula for obtaining wavelengths is applied and is stated below.

$$\lambda = (C/F)$$

C is the sound velocity, F is the frequency and λ is the wavelength

The wavelengths of English and Ika utterances produced using specific intonation are outlined below.

Table 1: Wavelengths of Ika Igbo and English intonation patterns (cm)

(FO Hertz)

Utterances/ Tunes	**W/L**	**FO**	**Utterances/ Tunes**	**W/L**	**FO**
I LR	145	235	**I LR**	159	214
II LR	231	147.5	**II LR**	221	154
III LR	258	132	**III LR**	193	176.5
IV LR	258	132	**IV LR**	204	167
V LR	200	170	**V LR**	150	227
VI LR	210	162	**VI LR**	217	156.5
VII LR	304	112	**VII LR**	184	184.5
VIII LR	283	120	**VIII LR**	158	215
IX HR	159	213.5	**IX HR**	123	276
X HR	152	223.5	**X HR**	102	333.5
XI HR	139	244	**XI HR**	168	202.5
XII HR	150	226	**XII HR**	127	268
XIII HR	88	385.5	**XIII HR**	113	300
XIV HR	151	224.5	**XIV HR**	147	231
XV HR	148	229	**XV HR**	150	227
XVI FR	127	268	**XVI FR**	131	260
XVII FR	121	280.5	**XVII FR**	162	210
XVIII FR	174	195	**XVIII FR**	202	168.5
XIX FR	110	308.5	**XIX FR**	145	234
XX FR	225	151	**XX FR**	147	232

XXI FR	268	127	**XXI FR**	231	147
XXII RF	194	175	**XXII RF**	136	249
XXIII RF	119	285	**XXIII RF**	194	175
XXIV RF	213	160	**XXIV RF**	275	123.5
XXV RF	209	162.5	**XXV RF**	131	259.5

4.0 Discussion (Implications of the wavelength measurement)

As can be seen from Table 1, utterances with higher fundamental frequencies have shorter wavelengths and those with lower FOs have longer wavelengths. This confirms the place or resonance theory which states that the louder a sound (frequency) the faster the rate of firing (wavelength). For the Low Rise utterances, all the English utterances, apart from the first one, utterance I, have low FO values and as is expected, their wavelength values are high. However, for the Ika Low Rise utterances, four out of eight of them have low FOs. These are utterances II, III,IV and VI. The rest have high FO values with their wavelength values being lower. However, the FO and wavelength values of Ika utterance VII stand out from the other LR utterances as its wavelength and FO values are the same, varying with only .5 (the wavelength value is 184 cm while the FO is 184.5 Hz). The difference in the FO and wavelength values between English and Ika Low Rise utterances may be as a result of the presence of tone in Ika. Also, the speaker's attitude could influence the difference as seen in the first English Low Rise utterance which has a high FO value. Generally therefore, we conclude that Low Rise utterances have low FOs and long wavelengths. For the High Rise utterances, all the English and Ika utterances have low FO values while having long wavelengths. This type of intonation,

therefore can be identified by these characteristics – low FOs and long wavelengths.

These characteristics, however, are not stable in Fall Rise and Rise Fall utterances. A look at the table above shows that for Fall Rise utterances, though both Ika and English utterances generally have higher values for FOs than wavelengths, both languages have two FR utterances that have higher values for wavelength – English utterances XX and XXI and Ika utterances XVIII and XXI. For the Rise Fall utterances, the FO values of three English utterances are lower than the wavelengths while one, utterance XXIII, has a higher FO value. Two of the Ika RF utterances, XXIII and XXIV, have lower FO values while two others, XXII and XXV, have higher FO values.

From the foregoing, it may be deceptive to try determining type of intonation through wavelength and FO values particularly for FR and RF tunes. Though there seems to be some sort of consistency in FO/wavelength relationship in some tunes like the HR and the RF, generally, this relationship is neither very predictable nor reliable as far as tune determination is concerned considering the inconsistencies in LR and FR. It is important to point out that the FO/wavelength relationship is more consistent for English utterances than Ika utterances. All English HR utterances showed the same pattern – high FO and short wavelength. English LR and RF generally showed a consistent pattern – low FO and long wavelengths; only one utterance deviated in both types of intonation. English Fall Rise utterances showed considerable instability. For Ika, there are a lot of inconsistencies in the utterances said in the four types of intonation. It may be worthwhile to study if the phonemes and attitudes of the speaker have effect on FO and wavelength values. Results from such a study may explain reasons for the

inconsistencies; only then can FO and wavelength values be used as yardstick to determine type of intonation.

5.0 Conclusion

This paper has revealed that though FO is an acoustic correlate of intonation, its relationship to wavelength cannot reliably be used as a cue to determining type of intonation, particularly for Ika Igbo. This is due to the inconsistencies in wavelength/FO values exhibited in the utterances bearing similar tunes. The English utterances manifested more stable characteristics for the HR, LR and RF intonation. The FO and wavelength values for FR are inconsistent for both Ika Igbo and English. Some of the Ika utterances produced in the four types of intonation manifested gross inconsistencies in FO and wavelength values. It is therefore important to discover the factors that cause these inconsistencies. Once these are defined, it could be possible to identify type of intonation through wavelength/FO values.

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