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CONSONANT ONSET AND TONE PATTERNS IN GA

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ABSTRACT

A recent acoustic study of Ga tones indicates that Ga uses seven tone patterns to distinguish meaning in words and syllables. These tone patterns include High, Low, High High, High Low, Low Low, High High Low, High High High. This study investigates how different onsets affect the different tone patterns in Ga. In this research, we investigate how syllable onset of different voicing, place of articulation and manner of articulation affect the tone patterns of the Ga syllable. Data is collected from two native speakers who read sentences in a frame: "say… only". F0 and duration of the syllables were analyzed using PRAAT. The results confirm earlier results from other studies that syllables with voiceless onset are likely to be longer and have a higher F0 than syllables with voiced onsets. In terms of places of articulation for the nasals, the tendency is that the palatal nasals have the lowest pitch contour for the L tone pattern followed by the alveolar and then the bilabial. For the H tone pattern, the alveolar has the highest pitch contour followed by the palatal and then the bilabial. Thus the paper suggests that any description of the tone patterns of language should include an investigation of the different onsets that a syllable can have. The study gives precise description of the tones of Ga and adds to the acoustic database of Ga language.

Keywords: Tones, PRAAT, Fundamental Frequency, Voicing, Place of articulation, Manner of Articulation, onset

INTRODUCTION

It is generally observed that there is consonantal perturbation of fundamental frequency (F0) of vowels following the consonant onset. It has been documented in a number of languages that vowel fundamental frequency (F0) at the onset of periodic voicing tends to be lower after voiced than after voiceless consonants (Hombert, J.-M., Ohala, J. J., Ewan, W. G. 1979; Lehiste, I., Peterson, G. E. 1961). The characteristics of the effect varied with the underlying intonation contours, (Silverman, K. 1986). Two different views on the directionality of consonantal influence of F0 are: the rise-fall view which maintains that F0 falls after voiceless stops but rises after voiced stops (e.g. Lehiste, I.,Peterson, G.E. 1961); and the no-rise view which asserts that F0 falls after all stops, with the slope being smaller in case of voiced stops e.g. Ohde, R. (1984).
F0 patterns in language which determine the tone patterns of language are thus determined by the consonant onset of the syllable which means that a high tone on a syllable for instance may not necessarily have the same features as a high tone on another syllable in the same language. Silverman (1986) showed that in certain intonational environments F0 could appear to rise after voiced stops therefore one needs to consider the surrounding F0 contours to accurately characterize consonantal perturbations. The articulation of tones is synchronized with the

syllable (Wong, Y.W. 2006b; Xu, Y. 1999; and Xu, Y., Wang, Q.E. 2001) and therefore the consonant may be temporally aligned in ordered to compare effects that consonants have on F0. This current paper reports the findings of a study into the consonantal perturbation of F0 in Ga, a tonal language spoken in the Greater Accra region of Ghana.

The source of the onset voicing effect has not yet been resolved though early accounts of the effect suggest an automatic, biomechanical effect of the mechanics of voicing (Halle, M., Stevens, K. N. 1971). Downward movement of the larynx, which aids voicing by increasing supraglottal volume, also decreases tautness of the vocal tract. This is naturally accompanied by a shortening and slackening of the vocal folds, the effect of which lowers fundamental frequency. Similarly, raising the larynx stiffens the vocal folds and this hinders vocal-fold vibration and manifesting as higher F0 on the following vowel (Honda, K., Hirai, H., Kusakawa, N. 1993; Hoole, P., Honda, K., Murano, E., Fuchs, S., Pape, D. 2004).

House and Fairbanks (1953) in a study in which they averaged F0 over the vowels in CVC syllables established that F0 was higher when the consonant was voiceless than when it was voiced. Lehiste and Peterson (1961) share the views of House and Fairbanks when their study yielded similar results. Both of these studies found out that the time course of the F0 contour varied according to the voicing of the initial consonant. With voiceless consonants, the peak F0 in the vowel occurred immediately after the consonant, but with voiced consonants the peak occurred at about the middle of the vowel.

Lea (1973) studied two types of utterances from two male speakers of American English: bisyllabic nonsense words *h*əˈCVC, in which C and V included nearly all the consonants and vowels of American English and pairs of bisyllabic words such as the noun and verb forms of “refuse.” These were recorded in isolation. For the nonsense syllables, in which the medial consonant always followed an unstressed syllable and preceded a stressed syllable, it was observed that the F0 contour following a voiced obstruent rises from a lower value at voice onset to a higher value at midvowel, while the *F*0 contour following a voiceless obstruent slopes down from voice onset to midvowel. However, for the second set of recordings, in which the medial consonant could precede or follow a stressed syllable, the results were more complicated, and Lea (1973) concluded that whether the *F*0 contour rises or falls at a CV transition is an interaction of both stress and segmental context.

In a study on American English, Ohde (1984) recorded data both in isolation and in carrier phrases. Ohde paired six voiceless aspirated and voiced stops with five vowels (/i/, /e/, /u/, /o/, /ɑ/) to form CVC syllables. The study indicated that though the F0 contour following voiceless stop consonants is higher than that following voiced stop consonants, it cannot be described as a rise-fall dichotomy. Rather, the F0 contour falls after both voiced and unvoiced consonants for his three male subjects.

Silverman (1984) observed the effects of voiced and voiceless obstruents on both preceding and following vowels in Southern British English. The obstruents were embedded in three-syllable nonsense words (e.g., /əˈpi:pi:p/), which were embedded in carrier phrases. The subjects were instructed to place lexical stress on the middle syllable of the nonsense word. For two male subjects, Silverman (1984) observed an effect of consonant voicing on the *F*0 of vowels that both precede and follow the consonant, with stressed syllables displaying a greater effect. He also found that *F*0 falls after both voiced and voiceless obstruents, in line with the Ohde (1984) data on stops.

This current study seeks to contribute to the discussion on the effect of consonant onset on the F0 of syllables. The study focuses on Ga and compares the tonal pattern of syllables with voiced onset with those with voiceless onsets. We also discuss the place and manner of articulation of the consonant onsets and how they manifest on the tonal contour of the syllable

THE CURRENT STUDY

In this study, we use Ga syllables made up of all possible onset consonants and the low back vowel /a/. The syllables were produced with the seven different tones to illicit different meanings. Data was collected by embedding syllables in the carrier frame "kɛɛmɔ ----- pɛ" (say … only). Two female speakers of 27years and 39 years old were used for the study. Speakers were native Ga speakers who have lived their entire lives among the Ga people of Teshie. The English glosses of the target syllables were given in parenthesis so as to elicit the appropriate words in Ga. This is done because the autographic representation of Ga does not make use of tone markings. Readers of Ga depend on the context of words to determine the meaning of the syllable. The syllables were selected in such a way to get different manners of articulation, different voicing and different places of articulation for the onset of the syllable. To look at consonantal effects, F0 influence from vowel height (Peterson, G.E., Barney, H.L. 1952) is minimized through the use of the central low vowel. Recordings was made using sony IC recorder and was later acquired or PRAAT. Measurements of F0 were recorded and analysed

MEASUREMENTS

The F0 values of pitch were measured at every 0.01 second of the utterance in order to plot the movement of the pitch from the voice onset to the end of the vowel. Duration of each syllable was also measured considering the duration of the onset, the vowel and the syllable as a whole.

RESULTS

The consonant onset effects of voicing, place, and manner of articulation on the pitch contour of each syllable are analysed in the sections that following.

EFFECT OF VOICING

The effect of voicing was examined by observing the tone patterns with /t/, /d/, /ʧ/ and /ʤ/ onsets. The results show that the High tone pattern in the voiced /d/ and voiceless /t/ environment have higher pitch height at onset for voiceless onset than the one with a voiced onset (212Hz and 202Hz respectively). The pattern for the syllable with voiceless onset falls slightly and intersetcts with the pattern with voiced onset and then the latter continues to drop before rising again to end near the height of the former.

The Low tone patterns for the two syllables show that voiceless onset syllables start with F0 higher than that with a voiced onset (161Hz and 148Hz respectively). The pitch heights for both syllables drop steadily through 137Hz till about 0.08s when they start rising again to end at about 144Hz for the voiced onset and 154Hz for the voiceless onset.

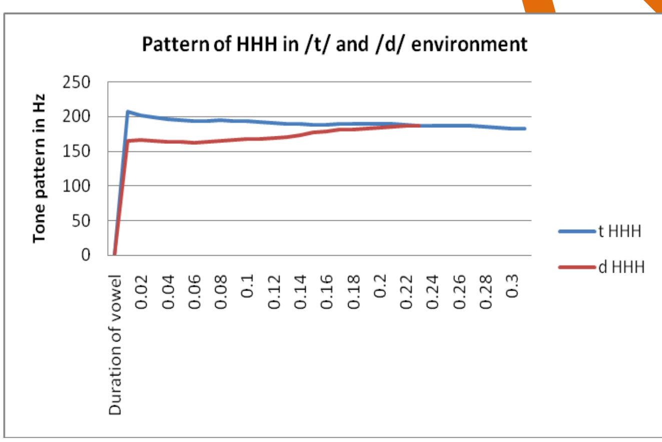
Table1: Mean F0 values of Tones with alveolar onset varying in voicing at onset

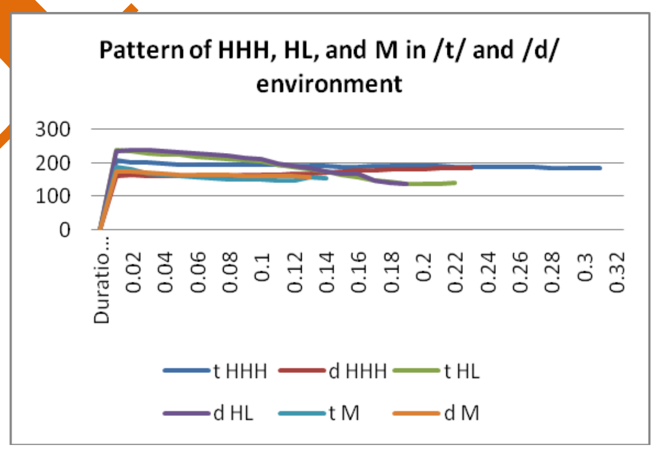
Tone Type	Vowel Duration (in sec)	Fundamental Frequency (in Hz) at different time (in seconds) of the utterance							
		0.01	0.05	0.10	0.15	0.20	0.25	0.30	0.35
t HHH	0.33	207	195	193	188	190	186	183	
d HHH	0.24	164	163	167	176	183			
t HL	0.23	238	223	203	165	138			
d HL	0.21	236	231	210	168				
t M	0.14	189	161	152					
d M	0.14	174	165	160					
t L	0.13	161	144	140					
d L	0.12	148	138	143					
t H	0.14	212	201	201					
d H	0.13	202	199	193					
t MH	0.22	179	168	171	175	184			
d MH	0.24	164	163	167	176	183			

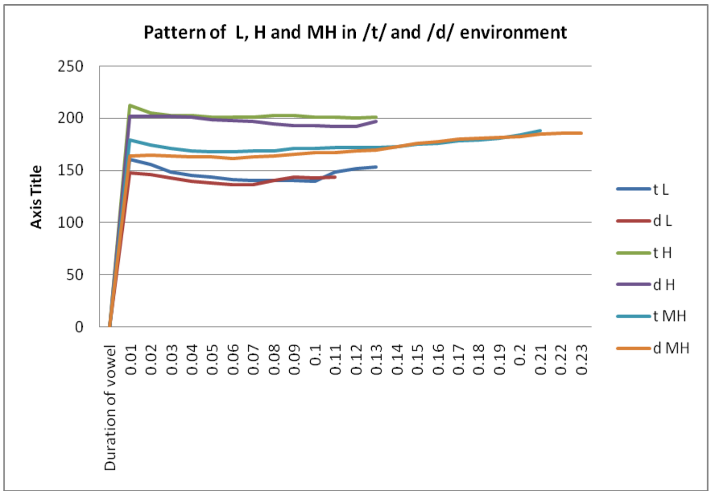
The results show HHH in /t/ environment starting with F0 height of 207Hz and falls slightly from around the middle half (about 191Hz) and ends at F0 of about 183Hz. For the voiced alveolar onset /d/, the HHH tone starts with pitch height of 164Hz and then starts rising steadily and by the end of it the pitch height (about 186Hz) is about that of the tone with the voiceless onset /t/. Thus the pitch starts higher for the voiceless onset than for the voiced onset.

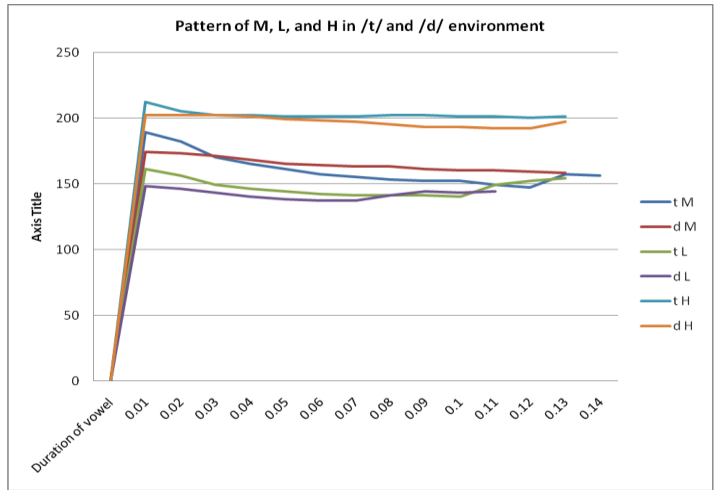
In the voiceless environment for the HL syllable, the F0 for both patterns started with about the same value though for the voiceless environment the pitch started slightly high (238Hz for /t/ onset and 236Hz for /d/ onset). In the first third of the duration of the patterns however, the tone pattern for the voiced environment went higher and by the middle of the utterance was about the same pitch height with the tone pattern in the voiceless environment.

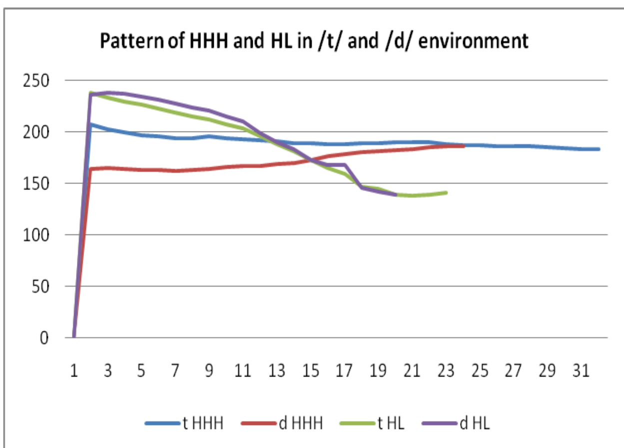
The data shows a tone pattern which could be described as Mid tone for the fact that it is located midpoint between the values for the High tone pattern and the low tone pattern. For the syllable with voiceless onset /t/, the tone pattern started with a higher pitch height of 189Hz and then started falling gradually. With a voiced onset /d/ however, the tone pattern started with a lower pitch height of 174Hz and that pitch level is maintained for a while before it starts falling. The slope is steeper for the syllable with voiceless onset than it is for that with a voiced onset. At about 0.04s of the course, the two tone patterns intersect and then the one with voiceless enviroment continues dropping to about 147Hz before it rises again to the height (158Hz) of the pattern with a voiced environment. Thus the mid tone pattern starts off at a height between the High and the low and then drops gradually to the pitch height of Low.

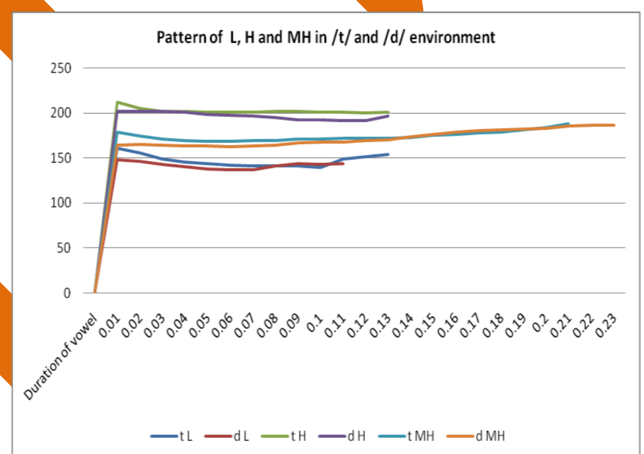












For palato alveolar affricate onsets, the movement of the tone patterns in voiced and voiceless environments differ from what pertains with the syllables with alveolar onsets. Whereas for the alveolar onsets the tone patterns start with high F0 values for syllables with voiceless onsets and lower F0 values for syllables with voiced onsets, the palato alveolars show tone patterns in which syllables with voiced onsets start with higher F0 values than syllables with voiceless onsets.

The High tone pattern in the syllable with voiceless palato alveolar onset starts with F0 value of about 213Hz while the syllable with voiced onset start with F0 of about 225Hz. Again the tone pattern for High in the voiced palato alveolar environment rises slightly till about a third of its course and then it continues with the initial F0 height. With the voicelss affricate onset however, the F0 value starts falling right from the beginning through its course till it ends with an F0 value of 183Hz.

The Low tone pattern in the voiced environment just like the High tone pattern, starts with a higher F0 value of 163Hz and continues with a downward trend through 142Hz around the midpoint and ends with a value of 133Hz. With a voiceless onset however, the tone pattern starts with a lower F0 value of about 159Hz and continues in a downward trend through 124Hz around the midpoint and then ends with F0 value of 120Hz. In a voiced palato alveolar environment the Low tone pattern presents higher F0 values compared to the pattern with a voiceless palato alveolar onset.

Table 2: Mean F0 values of Tones with palato alveolar onset varying in voicing at onset

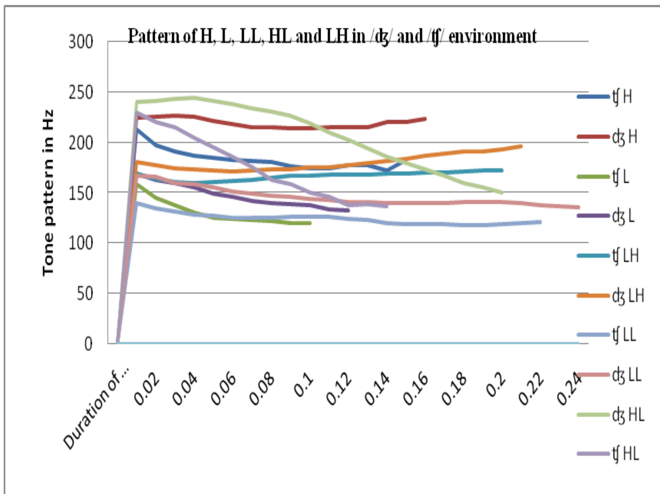
Tone Type	Vowel Duration (in sec)	Fundamental Frequency (in Hz) at different time (in seconds) of the utterance				
		0.01	0.05	0.10	0.15	0.20
ʧ H	0.15	213	185	174	183	
ʤ H	0.16	225	222	214	221	
ʧ L	0.11	159	126	120		
ʤ L	0.14	169	149	138		
ʧ LH	0.2	169	161	167	169	172
ʤ LH	0.22	180	172	175	184	193
ʧ LL	0.27	140	127	126	119	119
ʤ LL	0.25	167	156	144	140	141
ʤ HL	0.21	240	241	219	179	150

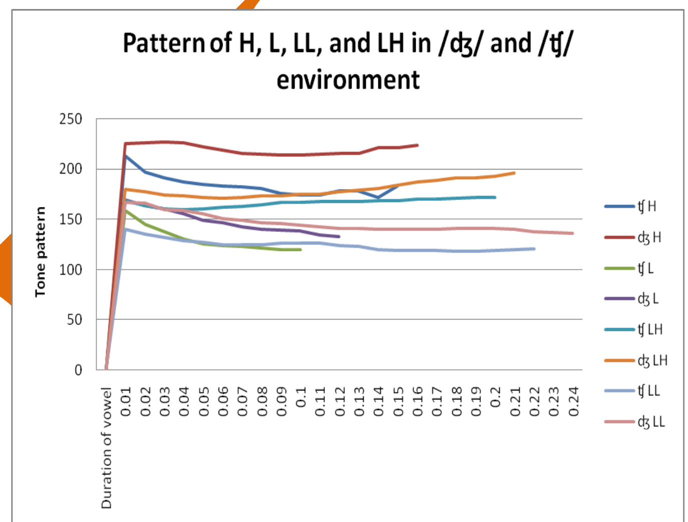
The trend in LL is no different from the trend in L tone pattern. LL with a voiceless palato alveolar onset starts with F0 value (140Hz) lower than that of L tone pattern and ends with F0 value of 120Hz which is slightly higher than that of the L tone pattern with a voiceless onset. The LL tone pattern with a voiced onset starts with F0 value of 167Hz and ends with F0 value of 137Hz.

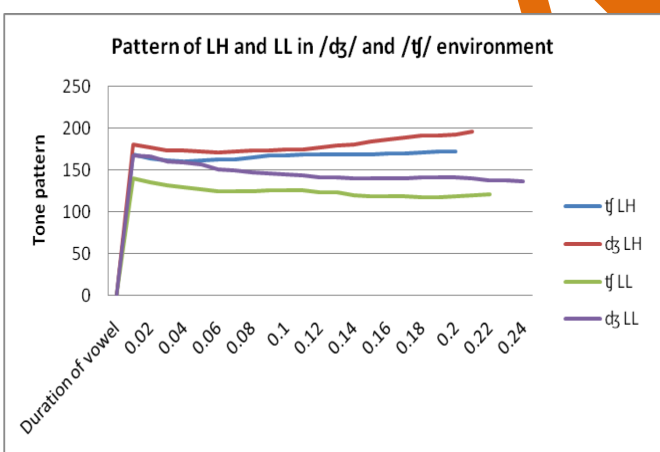
LH tone pattern in the voiceless palato alveolar environment starts with F0 value of 169Hz and ends with a value of 172Hz. In a voiceless palato alveolar environment however, the pattern starts with F0 value of 180Hz and ends with 196Hz.

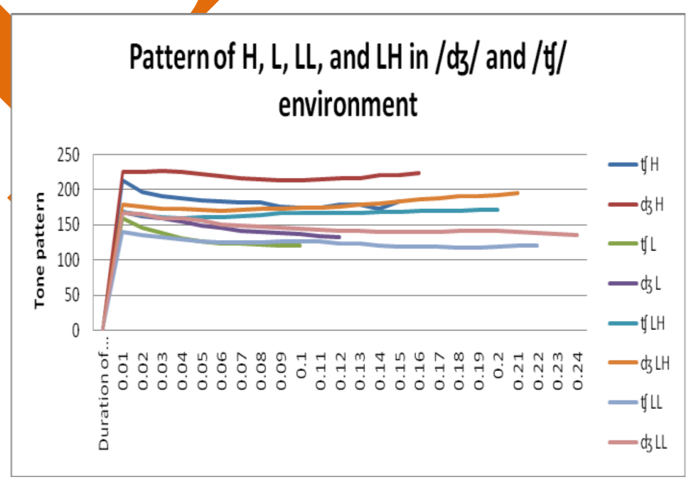
Thus in the palato alveolar environment the voiceless onset triggers lower F0 values especially at the onset of the vowel while the voiced onset triggers higher F0 values especially at the onset of the vowel.

The pattern of HL in the voiceless palato alveolar environment starts with an F0 value of 230Hz and drops gradually to end with an F0 value of 137Hz. With a voiced onset however, the pattern starts with an F0 value of 240Hz and rises to 244Hz before it starts to drop with a gentle slope to end with an F0 value of 150Hz.









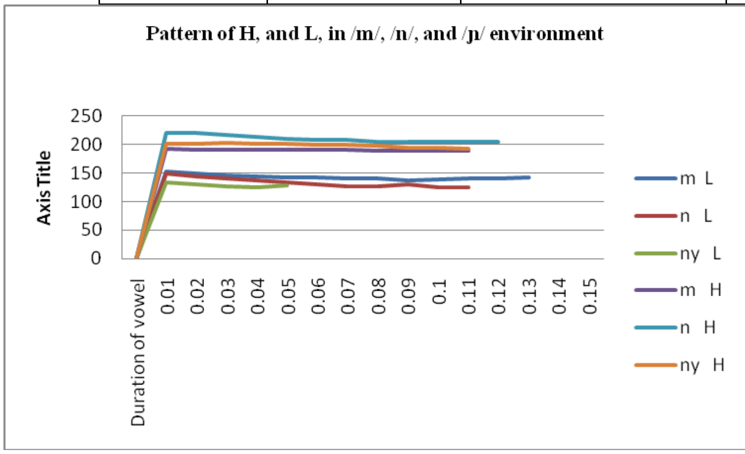
EFFECT OF PLACE OF ARTICULATION

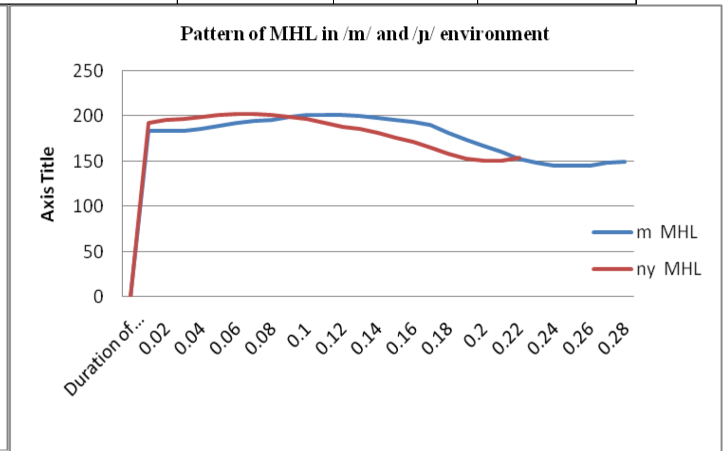
In order to ascertain the effect of place of articulation on the tone patterns, monosyllabic words with different place of articulation onsets were examined. Bilabial, alveolar, palate alveolar, palatal, and velar consonants were paired with the low back vowel /ɑ/. The results of this are presented as follows.

Table 3: Mean F0 values of Tones with onset varying in place of articulation

Tone Type	Vowel Duration (in sec)	Fundamental Frequency (in Hz) at different time (in seconds) of the utterance				
		0.01	0.05	0.10	0.15	0.20
m L	0.13	153	143	139		
n L	0.13	149	134	125		
ny L	0.06	134	128			
m H	0.12	192	191	188		
n H	0.12	220	210	204		
ny H	0.12	201	201	194		
m MH	0.21	176	171	174	179	186
n MH	0.23	159	155	157	160	163
ny MH	0.2	183	182	182	190	
m MHL	0.29	183	189	201	196	167
ny MHL	0.23	193	202	197	177	151
f H	0.13	212	195	196	196	
s H	0.16	217	205	205	206	
ʃ H	0.11	248	237	223		
f L	0.12	154	144	152		
s L	0.12	174	148	146	146	
ʃ L	0.13	174	149	145	140	
f LL	0.25	179	163	150	144	143
s LL	0.16	170	147	141	140	
ʃ LL	0.31	190	168	159	153	155
f HHL	0.38	214	206	203	201	199

ʃHHL	0.52	210	203	197	196	197





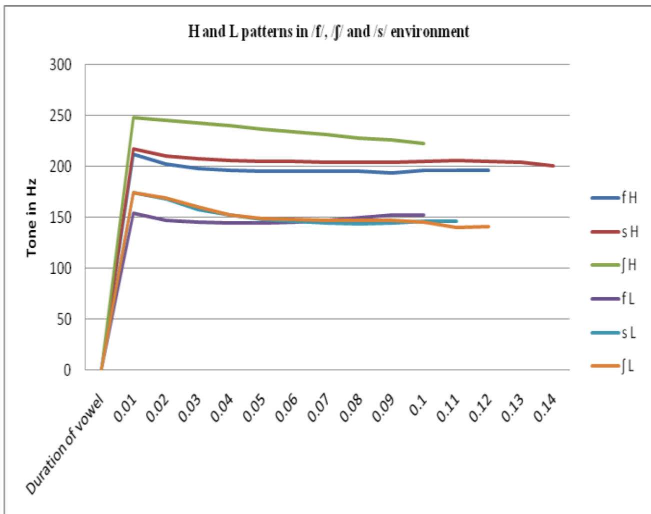
In the nasal environment, the behaviour of the tone patterns were observed in bilabial, alveolar and palatal sounds. The High tone pattern in the bilabial nasal environment starts with a fundamental frequency of 192Hz and is almost maintained at that frequency till the midpoint of its course when it starts falling (189Hz) gradually till it ends at a frequency of 188Hz. In the palatal environment, the High tone pattern starts off with a frequency of 201Hz and is kept at that frequency till the middle area of the course where it starts to fall till it ends at 193Hz. This tone pattern is slightly higher in fundamental frenquency than the pattern with a bilabial nasal onset. The alveolar nasal environment shows a pattern with the highest range of fundamental frequencies. The tone pattern starts with a fundamental frequency of 220Hz which starts to fall through 205Hz by the middle of its course and ends with a fundamental frequency of 204Hz. Thus for the High tone pattern in the nasal environment, the alveolar onset has the tendency of having the highest fundamental frequencies followed by the bilabial and then the palatal onset.

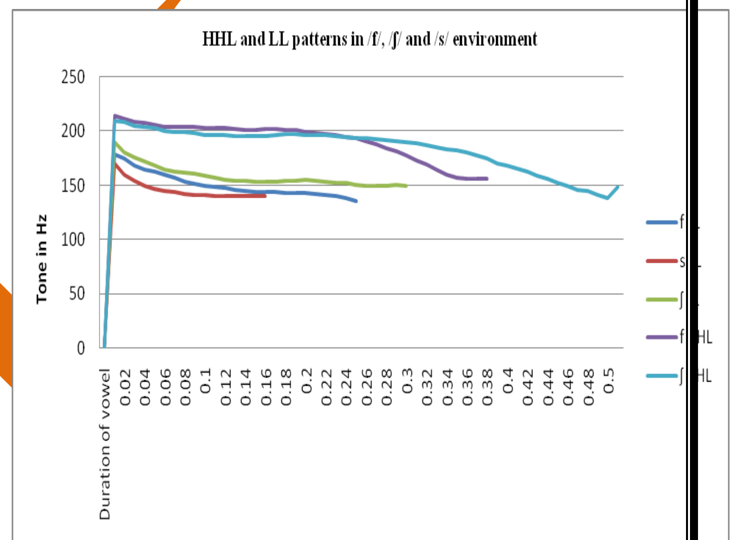
The Low tone pattern with a nasal onset has a different arrangement from the high tone. In the bilabial environment the pattern has the highest fundamental frequencies. It starts with a fundamental frequency of 153Hz and the F0 drops gradually through 139Hz at 0.09sec and ends with F0 of 142Hz at 0.13sec. In the alveolar onset, the Low tone pattern starts with a fundamental frequency of 149Hz and falls gradually to end with 124Hz. The pattern with the lowest fundamental frequencies in this environment is that with a palatal nasal onset. It starts with 134Hz of F0 and ends with 124Hz. The tone patterns of H and L in the nasal environment as far as the place of articulation is concerned do not differ in a uniform way.

The High tone pattern in a palato-alveolar fricative environment has higher F0 values than than in a labiodental and also alveolar environments. The pattern starts with a very high F0 of 248Hz and the F0 drops gradually till it ends with F0 of 223Hz. In an alveolar environment, the H tone pattern starts with a lower F0 value of 217Hz and drops gradually till it ends with F0 of 200Hz.

With a labiodental onset, the H tone pattern starts with F0 of 212Hz and drops gradually till 196Hz.

The behaviour of the Low tone pattern is slightly different from that of the High tone in the three fricative environments. With a palato-alveolar onset, the L tone pattern starts with a relatively high F0 of 174Hz and then drops to 141Hz in the end. The F0 value at the beginning of the L tone with an alveolar onset also starts with an F0 of 174Hz and then drops gradually till it ends with F0 of 146Hz.





EFFECT OF MANNER OF ARTICULATION

The tone patterns used to determine how consonant onset affect the tone pattern are the High and Low tones which could be observed with all the different onset types. Other tone patterns could be observed with different onset type but which did not run through all the onset types.

It was evident in the data that for the H tone pattern, syllables that have fricative onsets have the highest fundamental freqeucy at the onset. The pattern starts with F0 of 226Hz and drops gradually to end with F0 of 196Hz. The drop in F0 value is gentle from the beginning till it gets to the last third of the course at 0.11s were the drop is steeper.

Table 4: Mean F0 values of Tones with onset varying in manner of articulation

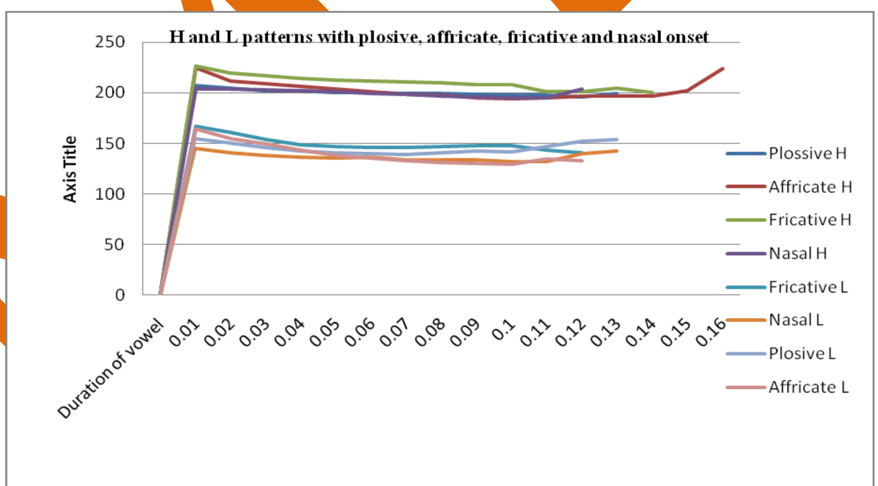
Tone Type	Vowel Duration (in sec)	Fundamental Frequency (in Hz) at different time (in seconds) of the utterance				
t HHH	0.33	207	195	193	188	190

d HHH	0.24	164	163	167	176	183
t HL	0.23	238	223	203	165	138
d HL	0.21	236	231	210	168	
t M	0.14	189	161	152		
d M	0.14	174	165	160		
t L	0.13	161	144	140		
d L	0.12	148	138	143		
t H	0.14	212	201	201		
d H	0.13	202	199	193		
t MH	0.22	179	168	171	175	184
d MH	0.24	164	163	167	176	183
ʧ H	0.15	213	185	174	183	
ʤ H	0.16	225	222	214	221	
ʧ L	0.11	159	126	120		
ʤ L	0.14	169	149	138		
ʧ LH	0.2	169	161	167	169	172
ʤ LH	0.22	180	172	175	184	193
ʧ LL	0.27	140	127	126	119	119
ʤ LL	0.25	167	156	144	140	141
ʤ HL	0.21	240	241	219	179	150
ʧ HL	0.16	230	196	151		
m L	0.13	153	143	139		
n L	0.13	149	134	125		
ny L	0.06	134	128			
m H	0.12	192	191	188		
n H	0.12	220	210	204		

ny H	0.12	201	201	194		
m MH	0.21	176	171	174	179	186
n MH	0.23	159	155	157	160	163
ny MH	0.2	183	182	182	190	
m MHL	0.29	183	189	201	196	167
ny MHL	0.23	193	202	197	177	151

With an affricate onset, the H tone pattern starts with an F0 value which is slightly lower than it is for the fricative. It starts with an F0 of 225Hz and then drops sharply at 0.01s (212Hz) and continues to drope gently till 0.14s where it rose again to end with F0 of 224Hz close to the F0 at the beginning.

The H tone pattern with plossive and nasal onsets have very close F0 values. The pattern with plosive onset starts with F0 of 207Hz and goes through a gentle fall to end with F0 of 197Hz. The pattern with nasal onset starts with an F0 of 204Hz and also goes through a gentle till point 0.11s where it shot up to end with 204Hz the F0 at the beginning.



The low tone pattern in all the onset types shows a steep drop in the first third of its course and then a gentle drop around the midpoint. It then rises again in the last third of its course for plosives, affricates and nasals but drops for fricatives

DISCUSSION

The study shows that the High tone pattern with alveolar plosive onsets have higher initial F0 values for syllables with voiceless onset than for syllables with voiced onsets (212Hz and 202Hz respectively). The pattern for the syllable with voiceless onset falls slightly and intersects the pattern with voiced onset and then continues to drop before rising again to end near the F0 of the voiced onset syllable. Meaning that with a voiceless onset, the F0 starts high and then drops to the value of the voiced onset. The low tone pattern behaves in the same manner as the high tone pattern though the drop in value for voiced onset patterns is more obvious in the low tone pattern. For HHH tone patterns also, the initial F0 is higher for the the voiceless onset syllables than for the voiced ones. Interestingly though, the tone pattern with voiced onset, rises by the middle of its duration to the F0 level of the syllable with voiceless onset. This occurred also in the HL tone pattern.

In the voiceless environment for the HL syllable, the F0 for both patterns started with about the same value though for the voiceless environment the pitch started slightly high (238Hz for /t/ onset and 236Hz for /d/ onset). In the first third of the duration of the patterns however, the tone pattern for the voiced environment went higher and by the middle of the utterance was about the same pitch height with the tone pattern in the voiceless environment.

The data shows a tone pattern which could be described as Mid tone for the fact that it is located midpoint between the values for the High tone pattern and the low tone pattern. For the syllable with voiceless onset /t/, the tone pattern started with a higher pitch height of 189Hz and then started falling gradually. With a voiced onset /d/ however, the tone pattern started with a lower pitch height of 174Hz and that pitch level is maintained for a while before it starts falling. The slope is steeper for the syllable with voiceless onset than it is for that with a voiced onset. At about 0.04s of the course, the two tone patterns intersect and then the one with voiceless enviroment continues dropping to about 147Hz before it rises again to the height (158Hz) of the pattern with a voiced environment. Thus the mid tone pattern starts off at a height between the High and the low and then drops gradually to the pitch height of Low.

For palato alveolar affricate onsets, the movement of the tone patterns in voiced and voiceless environments differ from what pertains with the syllables with alveolar onsets. Whereas for the alveolar onsets the tone patterns start with high F0 values for syllables with voiceless onsets and lower F0 values for syllables with voiced onsets, the palato alveolars show tone patterns in which syllables with voiced onsets start with higher F0 values than syllables with voiceless onsets.

The High tone pattern in the syllable with voiceless palato alveolar onset starts with F0 value of about 213Hz while the syllable with voiced onset start with F0 of about 225Hz. Again the tone pattern for High in the voiced palato alveolar environment rises slightly till about a third of its course and then it continues with the initial F0 height. With the voicelss affricate onset however, the F0 value starts falling right from the beginning through its course till it ends with an F0 value of 183Hz.

The Low tone pattern in the voiced environment just like the High tone pattern, starts with a higher F0 value of 163Hz and continues with a downward trend through 142Hz around the midpoint and ends with a value of 133Hz. With a voiceless onset however, the tone pattern starts with a lower F0 value of about 159Hz and continues in a downward trend through 124Hz around the midpoint and then ends with F0 value of 120Hz. In a voiced palato alveolar environment the Low tone pattern presents higher F0 values compared to the pattern with a voiceless palato alveolar onset.

CONCLUSION

The type of onset is very important in determining the pattern of tones by their acoustic correlates. However the effect observed from the onset is not unilateral. With Fricative onsets the High tone with a palato alveolar onset has the highest F0 values. This is followed by tone patterns with alveolar onset and then follows patterns with labiodental onset. For the Low tone with palato alveolar onset F0 is highest, then alveolar onset F0 follows and then labiodental onset F0.

In nasals, High tone with alveolar onset has the highest F0 values, then palatal onset follows and then bilabial onset. For Low tone with nasal onset, the bilabial onset has the highest F0 values, followed by the alveolar onset, and then the palatal onset.

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