# Variabilitily of F0 Peak Alignment in Moroccan Arabic Accentual Focus

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## Abstract

The present paper examines how phonetic duration due to syllable structure contributes to the alignment of F0 peaks in Moroccan Arabic. The F0 peak occurs within but near the end of the accented syllable if the vowel is phonetically long due its occurrence in a final CVC. If the accented vowel is phonetically short as in a penultimate CV, the F0 peak is aligned after the accented syllable.

## 1. Review of literature

### 1.1. F0 alignment

The fundamental frequency (F0) contour of a speech utterance is known to be a major acoustic manifestation of prosodic features such as intonation, stress, and tone. Such prosodic features are generally bound to syllables in many languages. This relationship is known as *association* in the autosegmental framework. However, it has been recently shown that the precise temporal alignment of F0 events with the segmental string is quite complex, and does not simply follow from the mere fact of association.

A well-known phenomenon of the mismatch between association and alignment is known as *peak delay*. Peak delay occurs when the F0 peak is aligned outside the syllable that carries the tone, pitch accent or focal prominence. Peak delay has been reported for a number of languages. Silverman & Pierrehumbert [1] found that F0 peaks associated with prenuclear rising pitch accents in English often occurred after the syllable with which they are intuitively associated. de Jong [2] found that the F0 peak associated with the initial tone in Korean often occurred after the end of the initial syllable. Prieto et al. [3] reported that in Mexican Spanish an F0 peak associated with a pitch accent often occurred after the stressed syllable unless the syllable was immediately followed by another stressed syllable in the following word. Ladd et al. [4] found that in English pre-nuclear accents, the F0 peak occurred around 40 ms after the offset of the accent-bearing syllable at normal speech rate. Ladd et al. [5] reported that in Dutch, the rising prenuclear pitch accent had two different alignment patterns for the phonologically long and short vowels. When the vowel in the accented syllable was phonologically long, the F0 peak usually occurred at the end of the vowel. When the vowel in the accented syllable was phonologically short, however, the F0 peak usually occurred in the following consonant. D'Imeprio [6] reported a length contrast that is similar to the Dutch case, though it exclusively depends on syllable structure. In Neapolitan Italian, open stressed syllables are characterised by the presence of long vowels, while closed stressed syllables only allow the presence of short vowels. The alignment of peaks in this language is later when the stressed vowel occurs in a closed syllable than when it occurs in an open syllable.

Factors that influence F0 peak variations are of three kinds: (a) phonetic such as speech rate and intrinsic vowel duration; (b) phonological such phonological vowel length; and (c) prosodic such as syllable structure, phrase boundary, focal prominence and tonal context (crowding, stress clash). In general, when a syllable is shortened due to phonetic factors, the F0 peak tends to move closer to the syllable offset. However, when a syllable is lengthened due to prosodic factors, or due to phonological length the F0 peak moves away from the syllable offset along with the onset ([1], [3] [7], [5]).

Much recent work on F0 alignment implies the existence of well-defined "targets" as well as segmental "anchors" to which the tones would be aligned. Overall, it shows that when the factors affecting tonal alignment are properly controlled, both F0 peaks and F0 valleys are consistently aligned with specific points in the segmental string ([4], [5], [7], [8]). Arvaniti et al. [8] reported that in Greek rising prenuclear accents, F0 valleys and F0 peaks had a relatively fixed alignment with segmental landmarks: F0 valleys were aligned near the onset of the accented syllable, and the F0 peaks were aligned just after the beginning of the first postaccentual vowel. Such stable alignment was not found to be affected by variations in the duration or the syllable composition of the accented syllable. Arvaniti et al.'s finding was corroborated in [4], where it was shown that the beginning and the end of rising accents in English were anchored to specific locations in the segmental string regardless of changes in segmental duration brought about by speech rate differences.

The consistency of segmental anchoring is believed to have either a perceptual (i.e., psychoacoustic) basis or a neurophysiological basis. The perceptual interpretation comes from studies indicating that small differences of alignment can create clearly perceptible differences of meaning [6]. The neurophysiological interpretation proposed by [9] is based on the biomechanic constraint according to which concurrent motor movements tend towards synchronisation when they continually reoccur at high speed. An explanation in terms of universal articulatory constraints, however, makes it difficult to account for cross-linguistic differences found between some languages. The alignment of the peaks of rising accents is significantly later in Greek (onset of the unaccented vowel) than in English or Dutch (following consonant). Differences of alignment between varieties of the same language were reported in a study by [10], in which Southern German speakers were found to align rising accents later than Northern speakers. Native aligment patterns were found to be carried over into adult acquired language [10, 11].

### 1.2 Prosodic features of Moroccan Arabic

A number of studies have been undertaken to account for the syllable structure of Moroccan Arabic (e.g. [12], [13], [14], [15]). The studies distinguish between three full vowels /a, i, u/ and an epenthetic schwa [ə]. It has been found that a syllable with a full vowel carries more weight than a syllable with the epenthetic [ə]. To account for the placement of stress in clitic-free words, two syllable types seem to be needed: a light CV syllable and a heavy CVC syllable (e.g. [12], [15], [16], [17]). Generally stress is located on the final syllable if it is heavy; otherwise, it is on the penultimate syllable (e.g. li'muna "orange", lal'man "the Germans"). Other relevant prosodic features of Moroccan Arabic are the following:

- CVC syllables are mainly found in word final (prepausal) contexts [12, 14];
- Such final CVC syllables are subject to vowel lengthening averaging 40% [12, 16];
- The lengthening in CVC sequences plays a role in enhancing the perception of word boundaries [18]: e.g. [ʒa#bfasu] "He came with his pick" vs [ʒaːb#fasu] "He brought with his pick"

Studies on the intonational patterns of Moroccan Arabic (MA) are rather scarce. One notable exception is Benkirane [18], which is a production/perception study of intonation in MA according to theme-rheme structure. Alignment patterns are investigated in Yeou [19] where it is shown that F0 peak alignment varies with focus, position and syllable duration.

The study reported here is intended to contribute to the line of research on F0 alignment that I have reviewed above, and to provide empirical data from a different language, MA. In particular, the study focuses on the contribution of syllable structure to the alignment of F0 peaks. As said above, vowels occuring in terminal CVC sequences are 40% longer than those in CVCV sequences. My prediction is that in words with CVCV sequences, the F0 peak would be much delayed occurring in the following unstressed syllable.

## 2. Method

### 2.1. Materials and subjects

The speech material was composed of two sentence groups containing target words at two locations in the sentence: Initial and medial. The target words are of two types: (a) words with terminal CVC sequences having final lexical stress: (/ka'man/ "cello", /mi'mun/ "Minun", /ka'mun/ "cumin", /lal'man/ "Germans", /ʔa'min/ "Amin"); and (b) words with terminal CVCV sequences having penult stress: (/mi'muna/, /ħa'lima/, /sa'lima/, /na'mima/, "all personal names, respectively", /dˁa'mana/ "guarantee"). The words were incorporated in the two sentence groups:

(1) ʒabt mˁafia ʔa'min lbarħ "She came with Amin yesterday"

(2) ʔa'min lli ʒabt mˁafia lbarħ "It was Amin that she came with yesterday."

Sentences (1) are (2) were produced with contrastive focus on the underlined word. Recorded prompt questions were played to subjects to elicit production of the target sentences. The narrow focus reading was prompted by a question such as "Did she come with Mohamed yesterday?" (for the answer sentence "She came with Amin yesterday") which requires narrow focus on the target word, in this example, "Amin".

Five native speakers of MA, 3 males (KY, MA, MZ) and 2 females (MK, LL) (mean age=36 years), volunteered for the study. All of them are from Casablanca, Morocco.

### 2.2. Recording and analysis procedures

The target sentences were repeated six times by the five subjects who listened to the prompt questions played through a loudspeaker. The signal was digitized at 11025 Hz in real time and stored on the computer's hard disk. The keywords were segmented on the basis of simultaneous visual displays of the waveform, wideband spectrograms and F0 contour using the Praat software [20]. The following four segmental landmarks were identified as in [4]: the onset of the stressed syllable (C0); the onset of the stressed vowel (V0); the end of the stressed vowel (C1). On the basis of these segmental points, the following durational measurements were extracted: (a) syllable duration; (b) vowel duration; (c) C1-to-F0max; (d) peak location (=100 x C1-to-F0max / syllable duration).

## 3. Results and discussion

### 3.1. Medial focus

Individual means and analysis results are reported in Table 1. The mean duration of the accented vowel in closed syllables (CVC) is longer compared to that in open syllables (CV): 167.5 ms vs. 110 ms. A paired *t*-test indicates that this difference is highly significant, $t(119) = 15.552$, $p < 0.0001$. Table 1 shows a difference in alignment of the F0 peak in open syllables vs. closed syllables. The mean C1-to-F0max value in open syllables is 24.1ms, but in closed syllables is -29.2 ms. Such difference is statistically significant, $t(119) = 17.086$, $p < 0.0001$. The positive value indicates that speakers align the F0 peak after the end of the stressed vowel. The F0 peak generally occurs on the following consonant as illustrated in Figure 1. In other cases it may even extend to the beginning of the unstressed vowel (especially for speaker LL). These results meet the central expectation of this experiment, namely that vowel phonetic length dependent on syllable structure has a significant effect on the F0 peak alignment in Moroccan Arabic. The findings corroborate those of Ladd et al. [5] for Dutch and D'Imperio [6] for Italian. However, unlike Moroccan Arabic, open stressed syllables in Italian are characterized by long vowels not short ones.

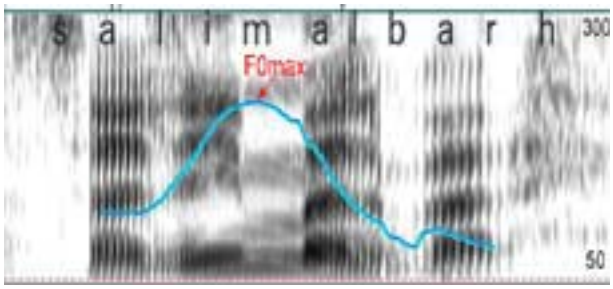


*Figure 1: F0 curve and spectrogram for the accented vowel /i/ occurring in an open syllable /sa**li**ma/. Note the F0 peak is placed in the middle of the following consonant /m/.*

Table 1. C1-to-F0max, peak location and vowel duration. Positive values mean that F0max is aligned after the end of the stressed vowel.

| | C1-to-F0max (ms) | | Peak location (%) | | Vowel duration (ms) | |
|---|---|---|---|---|---|---|
| | CV | CVC | CV | CVC | CV | CVC |
| MA | 10.8 | -44.9 | 110.1 | 79.5 | 85.4 | 135 |
| LL | 61.8 | 7.6 | 134.7 | 104.3 | 114 | 133.5 |
| MK | 11.8 | -32.9 | 107.4 | 88.9 | 108 | 186.7 |
| MZ | 11.8 | -46.4 | 113.7 | 86.2 | 131 | 214.6 |
| Mean | 24.1 | -29.2 | 116.5 | 89.7 | 110 | 167.5 |

| | C1-to-F0max (ms) | | Peak Location (%) | | Vowel duration (ms) | |
|---|---|---|---|---|---|---|
| | CV | CVC | CV | CVC | CV | CVC |
| KY | -58 | -68 | 78 | 78 | 216 | 240 |

### 3.2. The case of Speaker KY

Analysis of group CV measurements has excluded data from speaker KY because of his different tonal realisation. As clearly seen in Table 1, where all the other speakers would realise the F0 peak after the offset of the accented vowel in CV penult sequences, speaker KY produces the F0 peak within the accented vowel as indicated by the negative value (-58 ms). Informal listening to his sentences suggests that he may have used different F0 and duration patterns to signal focus. Close examination of his sentences shows that he consistently aligns the F0 peak in the general vicinity of the end of the accented vowel in both types of words (those with final CVCV or with final CVC syllables). Absence of peak delay in his production is probably due to his lengthening of the accented vowel occurring in a CV syllable which is normally characterised by a phonetically short vowel (see Figure 2).

Table 1 shows that the mean duration of such a vowel is 216 ms for speaker KY, as opposed to 110 ms for all speakers. It is reasonable to hypothesize that thanks to this lengthening, there is no time pressure affecting the alignment of the F0 peak. There is sufficient time to realise the F0 rise fully during the accented vowel.

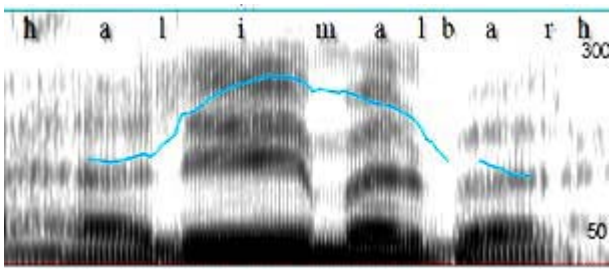


*Figure 2: F0 curve and spectrogram for the accented vowel /i/ occurring in an open syllable /ħa**li**ma/ (speaker KY). Note the lengthening of the vowel within which the F0 peak is aligned.*

### 3.3. Initial focus

A visual inspection of the F0 contours along with informal listening of the sentences having initial focus reveal the following patterns:

- The utterances correspond to one unique intonation phrase; they are not divided into intonational phrases.
- The placement of contrastive focus is shifted forward from the lexically stressed vowel to the unstressed one. Figure 3 shows such a pitch accent shift. The domain of accentual focus in the word [ħa'lima] is shifted from the canonical penultimate syllable [li] to the final [ma]. There is a thus a misalignment between focus and stress.
- With the exception of speaker KY, such misalignment is realised by all speakers in 87.2% of cases. Individual percentages of occurrence are as follows: MA, 100%; LL, 100%; MZ, 100%; LL, 81%; MK, 55%.

Because of the consistency of the occurrence of the pitch accent shift, it is not possible to compare the alignment data from CVCV sequences with CVC ones. The segmental context as well as the vowel category are not the same. Through visual inspection of the F0 contours, however, we notice that peak delay occurs in most cases of initial-focus CVCV words as in medially-focus ones. Since the final vowel that receives accent pitch is phonetically short (mean value across speakers is 68 ms), the F0 peak usually occurs on the consonant [ll] of the relative marker [lli]. There a few cases where it even extends to the beginning of the vowel [i] as shown in Figure 3. Figure 4 shows that in words with CVC syllables, F0 peaks align late but at the end of the phonetically long vowel (mean duration value across speakers is 160 ms).

Accentual focus shift seems to be the result of independently observed preferences for stressing heavy CVC syllables. In MA, there seems to be no prosodic requirement to ensure that focal prominence appears in the position where lexical stress falls. What happens in a sentence like "ħa'lima lli ʒabt mʕafia lbarħ" (It was Halima that she came with yesterday) is that the final syllable /ma/ is syllabified with the consonant of the relative marker /lli/, resulting in a CVC syllable which is favourably disposed to attract stress. The shift of the F0 rise from the penultimate syllable to the final one has been reported to occur in MA by [18].

As with sentence-medial focus, speaker KY produces a different tonal realisation for sentence-initial focus. Where all the other speakers would realise pitch accent shift, speaker KY produces the F0 peak on the canonically stressed vowel. He also places the F0 peak within the accented vowel in both types of words (those with final CVCV or with final CVC syllables). Absence of peak delay in his production might be explained again by the presence of an important lengthening in the accented vowel. We should note here that extended lengthening can be used in MA as a different strategy to indicate focus. In such case, it is possible to double or even triple the vowel duration as an alternative to expanded pitch excursion and peak delay; duration would become the strongest cue to accent perception. However such lengthening codes different semantics depending on the context. In the present data, it seems to be used to engage the listener's attention to the confidence/certainty the speaker has of the information he is focusing on. This information even appears to him as common knowledge or as something established. On

the other hand, later peaks seem to enhance contrastiveness (new content) and convey the speaker's insistence on excluding a stated alternative.

## 4. Conclusion

The results reported above show that for accented vowels occurring in focused words in medial or initial positions, peak location is very sensitive to differences in duration, which are mainly brought by differences of syllabic structure. Peak delay occurs in final CVCV sequences but not in CVC ones.
In addition, findings point to a different type of constraint on the timing of F0 peaks apparently related to communicative effects. One speaker in this study signals contrastive focus much more by lengthening rather than by extended tonal range. Such lengthening results in the occurrence of the F0 peak within the accented vowel, thereby avoiding peak delay. This points to the importance of taking into account pragmatic/discoursal effects to account for F0 peak variations [21, 9, 22].

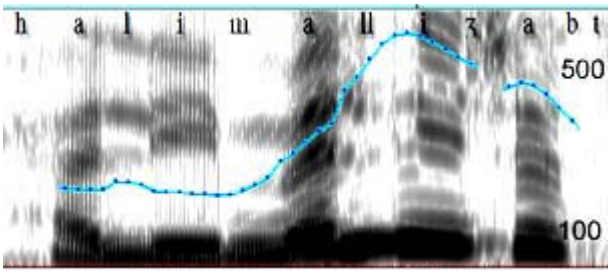


*Figure 3: F0 curve and spectrogram for /ħali**ma** lli ʒabt/. Note the pitch accent is shifted to the final syllable /ma/ and the F0 peak is aligned after the accented vowel*

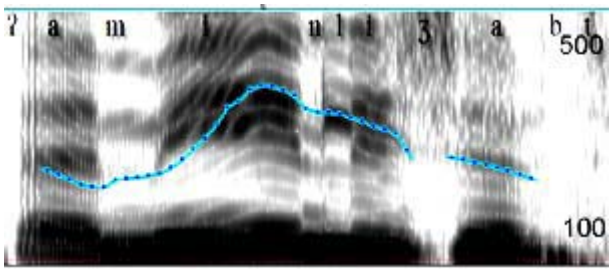


*Figure 4: : F0 curve and spectrogram for /ʔa**min** lli ʒabt/. The F0 peak is aligned within the accented vowel in the word /ʔa**min**/ (speaker LL).*

## 5. References


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