

Effects of focus, position and syllable structure on F0 alignment patterns in Arabic

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Résumé – Abstract

The present paper examines how factors such as focus, sentence position and syllable structure contribute to the alignment of F0 (fundamental frequency) contours in Arabic. Five Moroccan Arabic speakers were recorded reading declarative sentences with or without narrow focus at different positions. The results indicate that F0 peak placement is affected by variations in the duration of the stressed syllable. A detailed examination of the F0 events during the stressed syllable demonstrates that: (1) the location of the F0 valley remains stable across focus status and sentence position (a few milliseconds after the onset of the syllable); (2) in final position, the F0 peak occurs around the middle of the syllable; (3) in non-final positions, the F0 peak occurs within but near the end of the stressed syllable if the vowel is phonetically long; (4) if the stressed vowel is phonetically short due its occurrence in a CVCV sequence, the F0 peak is aligned during the following consonant.

Keywords – Mots Clés

Alignement des pics de F0, focalisation, intonation arabe
F0 alignment, Peak delay, focus, Arabic intonation

1 Introduction

A number of recent studies have demonstrated substantial regularities in the way F0 movements are aligned with the segmental string (Prieto *et al.*, 1995; Arvaniti *et al.*, 1998; Xu, 1998; Ladd *et al.*, 1999). For example, in their study of rising prenuclear pitch accents in Greek, Arvaniti *et al.* (1998) showed that the rise begins near the onset of the stressed vowel and peaks on the following unstressed vowel. Such alignment is realised independent of syllable composition and duration. The results of Arvaniti *et al.* (1998) were corroborated in a

study by Ladd *et al.* (1999) in which it was shown that the beginning and the end of the F0 rise in English prenuclear accents are anchored to specific points in the segmental structure which are unaffected by speech rate differences. Factors that influence F0 alignment 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. 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 (Prieto *et al.*, 1995; Ladd *et al.*, 2000). The objective of the study reported here to contribute to the line of research that I have just reviewed, and to provide empirical data on F0 alignment from a different language, Moroccan Arabic. In particular, the study examines the contributions of factors such as focus, sentence position and syllable structure to the alignment of F0 contours.

2 Method

2.1 Materials and subjects

The speech material was composed of three sentence groups containing five target words at three locations in the sentence: beginning, middle and end. The target words (/ka'man/ "cello", /mi'mun/ "Minun", /ka'mun/ "cumin", /lalm'an/ "Germans", /ʔa'min/ "Amin") were chosen according to the following criteria: (a) all the words have final lexical stress; (b) the consonants flanking the stressed vowel are all sonorant consonants. The words were incorporated in the three sentence groups: (1) *ʔabt mʔafia ʔa'min* "Yesterday, she came with Amin." (2) *ʔabt mʔafia ʔa'min lbarħ* "She came with Amin yesterday." (3) *ʔa'min lli ʔabt mʔafia lbarħ* "It was Amin that she came with yesterday." Sentences (1) and (2) were produced in two focus contexts: no focus and narrow focus on the underlined word. Sentence (3), which is a cleft-like sentence having the relative marker /lli/, was produced only in the focus condition. Recorded prompt questions were played to subjects to elicit production of the target sentences.

Five native speakers of Moroccan Arabic, 3 males (KY, MA, MZ) and 2 females (MK, LL) (mean age=36 years), volunteered for the study. All of them have lived in Casablanca since their childhood.

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. Speech samples were recorded by a condenser microphone connected to a PC. The signal was digitised 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 speech analysis system (Boersma and Weenik, 1992). For every test syllable F0 minima and F0 maxima of the target pitch accent were manually extracted, as shown in Figure 1. Moreover, the following four segmental landmarks were identified as in Ladd *et al.* (1999): 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 consisting of syllable onset duration and vowel duration; (b) C0-to-F0min; (b) F0min-to-C0; (c) C0-to-F0max; and (d) F0max-to-C1.

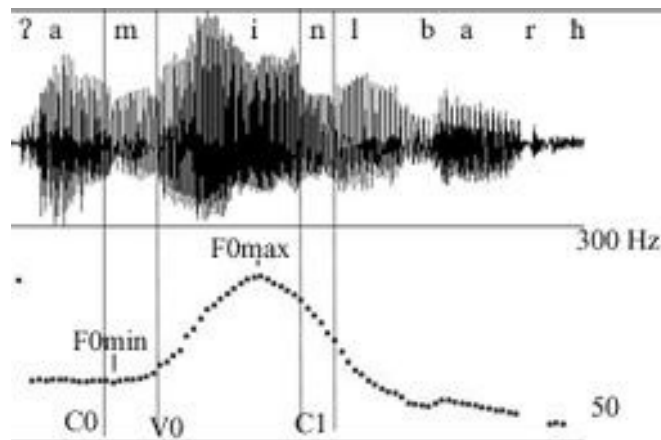


Figure 1 : Waveform and F0 track showing the measurements points obtained.

3 Analysis and results

3.1 Alignment of F0 Peaks and F0 valleys

3.1.1 Effect of focus and position

The effect of focus was generally found to be large for all the measurements. Under focus, the F0max associated with the accented syllable becomes higher, the rise size becomes larger, the rise speed becomes faster and duration longer. Similar duration and F0 attributes of focus have been established by several investigators for English among other languages (e.g. Cooper *et al.*, 1985; Xu and Xu, in press). Table 1 gives mean values of various measurements relating to the alignment between syllable boundaries and F0 peak in different focus and position conditions. Two-way repeated-measure ANOVAs were performed on these measurements with focus and position as the independent variables. All the probability values were found to be less than 0.05. Table 1 shows a clear effect of position on the location of the F0 peak. F0 peaks tend to shift leftwards as the position of the accented syllable approaches the end of the sentence. Syllable duration increases with position in the following manner: initial < medial < final.

| | Peak location (%) | | F0max-to-C1 (ms) | | C0-to-F0max (ms) | | Syllable duration (ms) | |
|---------|-------------------|---------|------------------|----------|------------------|----------|------------------------|----------|
| | +F | -F | +F | -F | +F | -F | +F | -F |
| Final | 61 (6) | 52 (11) | 115 (25) | 109 (20) | 177 (31) | 124 (44) | 292 (42) | 233 (31) |
| Medial | 88 (10) | 87 (16) | 37 (28) | 22 (28) | 234 (39) | 166 (38) | 271 (50) | 188 (21) |
| Initial | 99 (12) | ----- | 5 (20) | ----- | 241 (39) | ----- | 246 (40) | ----- |

Table 1: Mean values of F0max-to-C1, C0-to-F0max and Syllable duration, together with Peak location (=100 x F0max-to-C1 / Syllable duration) broken down by focus and position.

3.1.2 Correlation between F0 peak alignment and syllable duration

The results reported so far indicate that the F0 peak alignment varies with both focus and position. To investigate the underlying sources of such observed variation, a set of linear regression analyses were performed using syllable duration as predictor and both F0max-to-C1 and C0-to-F0max as dependent variables. Comparison of these two variables can indicate which measure is more sensitive to syllable structure. As can be seen in Table 2, the r^2 values are quite large suggesting that the location of F0 peak is significantly correlated with syllable duration. The r^2 values are much higher when C0-to-F0max is regressed over syllable duration in all conditions of the experiment. This indicates that in Moroccan Arabic, as in Mexican Spanish and English, F0 peaks are not located at some fixed distance in time relative to the onset of the syllable, but are affected by the duration of the syllable (van Santen and Hirschberg, 1994; Prieto *et al.*, 1995). It also seems that in Moroccan Arabic, the onset of the stressed syllable (C0) is a more appropriate reference point for the F0 peak alignment than the end of the stressed syllable (C1).

| | F0max-to-C1 | | C0-to-F0max | |
|---------|-------------|-------|-------------|-------|
| | +F | -F | +F | -F |
| Final | 0.642 | 0.377 | 0.631 | 0.538 |
| Medial | 0.287 | 0.276 | 0.635 | 0.527 |
| Initial | 0.376 | ----- | 0.867 | ----- |

Table 2 : r^2 values corresponding to the correlation between syllable duration and two temporal intervals (F0max-to-C1 or C0-to-F0max).

3.1.3 Alignment of F0 valleys

The analysis of the location of F0 valleys, measured as the temporal distance from C0 to F0min, shows that the F0 valley is aligned close the onset of the syllable. Mean values of C1-to-F0min in all conditions range between 8 ms and 10.8 ms, indicating that the effect of focus and position on the alignment of F0 valleys is too small to be significant. This result replicates the findings of many studies that the F0 valley aligns close to the syllable onset (e.g. Prieto *et al.*, 1995 for Mexican Spanish; Ladd *et al.*, 1999; Xu and Xu, in press for English).

3.2 Effect of syllable structure on F0 peak alignment

The results reported above demonstrate very clearly that for stressed vowels occurring in words with final CVC sequences, peak location is very sensitive to syllable duration and sentence position. In general, as syllable duration increases, peak delay (i.e., the interval from C0 to F0max) also increases. However, when a vowel is lengthened by an upcoming sentence final boundary, peak delay values tend to decrease. To further investigate to what extent the effect of syllable duration on the location of F0 peak is regular, another experiment was designed using words with final CVC sequences as controls and comparing these to words with a final CVCV structure having penultimate stress. Such a comparison provides us with an ideal test-bed for verifying the hypothesis that the shortened duration of an accented syllable pushes the F0 location rightward. Benkirane (1999) reports that in Moroccan Arabic, vowels occurring in terminal CVC sequences (closed syllables) are 40 % longer than those in

CVCV sequences (open syllables). My prediction is that in words with CVCV sequences (i.e., open syllables), the F0 peak would be much delayed occurring in the following unstressed syllable. To limit the range of variability and thereby make for more stable and more interpretable results, the test words were investigated only in the medial position and under focus. The test words (/mi'muna/, /ha'lima/, /sa'lima/, /na'mima/, /d'a'mana/) were inserted in the sentence “zabt m'afia (...) lbarh” as in the previous experiment.

Individual means and analysis results are reported in Table 3. 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 3 shows a difference in alignment of the F0 peak in open syllables vs. closed syllables. The mean F0max-to-C1 value in open syllables is -24.1ms, and in closed syllables 29.2 ms. This difference is statistically significant, $t(119) = 17.086, p < 0.0001$. The negative value indicates that speakers align the F0 peak after the end of the stressed vowel, i.e., in the following consonant as illustrated in Figure 2. These results meet the central expectation of this experiment, namely that vowel phonetic length dependent on syllable structure has an a significant effect on the F0 peak alignment in Moroccan Arabic. The findings also corroborate those of Ladd *et al.* (2000) who report that phonological vowel length influences the alignment of the F0 peak in Dutch. Specifically, the F0 peak is aligned at the end of the vowel if the stressed syllable contains a long vowel, but during the following consonant if the stressed syllable contains a short vowel. D'Imperio (2000) also investigated the effect of vowel duration differences due to syllable structure (open vs. closed syllable) in Italian and found the effect to be significant. However, unlike Moroccan Arabic, open stressed syllables in Italian are characterised by long vowels not short ones.

| Speaker | F0max-to-C1 (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 |
| Overall | -24.1 | 29.2 | 116.5 | 89.7 | 110 | 167.5 |

Table 3 : Means and individual values of F0max-to-C1, peak location and vowel duration. Negative values mean that F0max is aligned after the end of the stressed vowel.

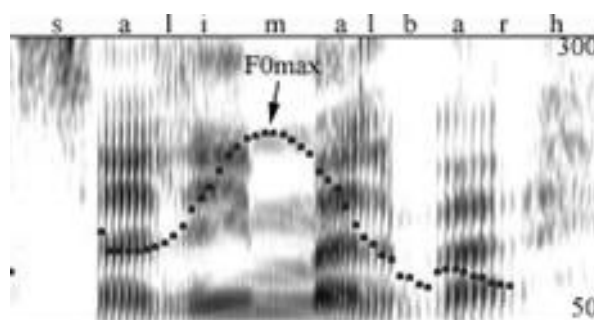


Figure 2: F0 curve and spectrogram for the accented vowel /i/ in an open syllable. Note the F0 peak is placed in the middle of the following consonant /m/.

4 Conclusion

The results of this study tend to demonstrate the importance of factors such as focus, position and syllable structure in the prediction of the F0 peak in Moroccan Arabic. Overall, the findings are almost entirely in line with well-established data. The hypothesis that F0 peaks are timed to occur at invariant fixed locations was not supported by the data. The effects of prosodic and phonetic factors on F0 alignment in Moroccan Arabic seem to work in the same fashion as in other languages, indicating that this phenomenon may be governed by general articulatory or perceptual constraints.

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