F0 ALIGNMENT PATTERNS IN ARABIC DIALECTS

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ABSTRACT

A comparison of F0 alignment values was carried out for three Arabic dialects (Moroccan Arabic, Kuwaiti Arabic and Yemeni Arabic) using five speakers from each dialect. Clear differences found in alignment enable separation of Moroccan Arabic from the two other dialects: a) values of the F0 valley differed significantly, with Moroccan Arabic showing a later synchronisation than Kuwaiti Arabic and Yemeni Arabic; b) there was variation as to the effect of syllable structure on F0 peaks. The effect is not significant in Yemeni Arabic and Kuwaiti Arabic as the F0 peak is aligned within the stressed vowel in both CV: and CV:C. In Moroccan Arabic, however, the effect of syllable structure is significant: the F0 peak is earlier in closed syllables than open syllables.

Keywords: Arabic intonation, F0 alignment.

1. INTRODUCTION

1.1. Cross-dialectal variability in Arabic

Arabic, a language spoken by more than 200 million people, has three different forms: Classical Arabic, Modern Standard Arabic and Dialectal Arabic. Dialectal Arabic, which is regionally based, is spoken as native tongue. Among other linguistic differences, the dialects exhibit phonological differences in vowel structure, consonantal production and prosodic structure. Experimental studies dealing with extensive phonetic comparisons across Arabic dialects are not abundant, unlike the case of Indo-European languages like English, German and Spanish. Recently, there has been a growing interest in addressing dialectical variation by studying either segmental or suprasegmental parameters. At the segmental level, it was shown that locus equations, which encode coarticulation, varied according to dialectal origin [6]. At the prosodic level, some studies investigated speech rhythm on the basis of durational measures, namely percentage of vocalic intervals and standard deviation of consonantal intervals [7, 10, 11]. In Arabic Eastern dialects, the proportion of vocalic intervals was found to be higher and the standard deviation of consonantal intervals was lower, compared with Western dialects, which makes the latter more stress-timed than the former. Such rhythm variability was shown to be correlated with vowel duration and frequency of syllable types. Another study [18] showed that prosodic automatic modelling was successful in automatically identifying Arabic dialects, which makes cross-dialectal prosodic comparisons promising.

1.2. Cross-linguistic variation in F0 alignment

Fundamental frequency (F0) alignment refers to how F0 contours are temporally synchronized with specific points in the segmental string. A number of studies have demonstrated substantial consistency in such alignment: e.g. [1, 19, 16]. Specifically, it was shown that the beginning of the F0 rise in non-final accents is aligned quite precisely with the onset of the accented syllable. There are, however, cross-linguistic phonetic differences in the exact alignment of the F0 peak. In Greek and in German, the peak is aligned after the onset of the first post-accentual vowel. In English, it is aligned earlier, typically occurring around 40 ms after the offset of the accented vowel, but within the accented syllable. In Dutch, phonological vowel length has a significant influence on the alignment of the F0 peak, which is aligned 12 ms before the end of the vowel if the stressed syllable contains a long vowel, but 24.8 ms into the following consonant if the stressed syllable contains a short vowel [17]. F0 alignment has also been studied in Dialectal Arabic: Moroccan Arabic [20, 21], Egyptian Arabic [12, 13] and Lebanese Arabic [6].

Comparison of F0 alignment across languages on the basis of reported findings of published studies has its limits. On the one hand, the speech material, the vowel system and the prosodic

patterns are different. On the other hand, such comparison would presuppose that these languages have the same functional timing in their intonational systems [14]. It is possible to have reliable results of F0 alignment across varieties of the same language by using parallel speech material and measurements. The present study aims at investigating F0 alignment patterns in read speech from three Arabic dialects. The study of cross-dialectal variability is motivated by several reasons. First variability constitutes a substantial source of information for prosodic typology. Second, such source of information can be relevant for Arabic dialect modelling aiming at improving automatic speech recognition for Arabic. Finally, investigating dialectal variability enhances our understanding of the impact of dialect patterns on the pronunciation of Modern Standard Arabic.

2. METHODOLOGY

2.1. Materials and subjects

The speech material consisted of 10 declarative sentences containing two types of target words: (a) words with terminal [CV:C] sequences having final lexical stress: ([ħaliːm], [saliːm], [ʔamiːn], [mimuːn], [ʒaliːl]); and (b) words with terminal CVCV: sequences having penult stress: ([ħaliːma], [saliːma], [ʔamiːna], [mimuːna], [ʒaliːla]). The words, which are all personal names, were incorporated in the following carrier sentence: ʒabt m(a)ʕaña ʔamin lbarħ/mbariħ "She came with Amin yesterday." The data was read by 5 native speakers of each Arabic dialect (Moroccan Arabic, Kuwaiti Arabic, Yemeni Arabic). Each dialect group contained 3 males and 2 females who were all in their twenties. Speech samples were recorded using professional equipment. The keywords were segmented on the basis of simultaneous visual displays of the waveform, wideband spectrograms and F0 contour using PRAAT. For every test syllable F0 minima and F0 maxima of the target pitch accent were manually extracted. Moreover, the following three segmental anchor points were identified as in [16]: a) the onset of the stressed syllable (C0); the onset of the stressed vowel (V0); the end of the stressed vowel (C1); and the onset of the following unstressed vowel (V1). From these three segmental points, the following durational measurements were extracted: 1) C0-to-F0min (F0 valley alignment); 2) C1-to-F0max (F0 peak alignment); 3) C0-to-C1 (Syllable duration); and 4) V0-to-C1 (Vowel duration).

3. RESULTS

3.1. Alignment of F0 peak and F0 valley

3.1.1 Alignment of F0 valley

A two-way ANOVA was conducted to assess whether differences in F0 valley alignment were significant. There was a significant main effect of dialect $F(1, 147)=5.141$, $p=.007$) but not syllable structure $F(1, 147)= 3.507$, $p=.063$). The interaction between the two factors was not significant $F(1, 147)=.683$, $p=.507$). As shown by Table 1, the F0 valley is aligned close to the onset of the syllable in both syllable types for the three groups of speakers. The alignment is a little earlier in CV: than in CV:C for the Kuwaitis and the Yemenis. ANOVAs were conducted separately for each group to see if alignment of F0 valley varies with syllable structure. Results revealed that the F0 valley does not vary with syllable structure for the three groups: the Moroccans, $F(1,98)=.082$, p=.775, the Kuwaitis, $F(1,98)=.182$, p=.671, and the Yemenis, $F(1,98)=2.597$, p=.110. This replicates the findings of many studies showing that the F0 valley is synchronized with syllable onset in a stable manner [16, 17].

Table1: Mean alignment data for all speakers in ms. Negative values indicate alignment before C1 or C0.

	F0max-to-C1		F0min-to-C0	
	[CV:C]	[CV:]	[CV:C]	[CV:]
Moroccan	-28,9	2,5	5,4	4,9
Kuwaiti	-40,9	-26,2	2,3	-3,3
Yemeni	-27,7	-28,3	1,3	-2,4

3.1.2 Alignment of F0 peak

Table 1 shows that there are differences in F0 peak alignment across the Arabic dialects. The peak is earlier for vowels in CV:C than in CV: in Moroccan Arabic and Kuwaiti Arabic, but is stable in Yemeni Arabic. Overall, the F0 peaks are realized within the stressed vowel, except in Moroccan Arabic where it is aligned just after the stressed vowel in open syllables [CV:]. In closed syllables [CV:C], F0 peak alignment is earlier in Kuwaiti Arabic than in Yemeni Arabic and Moroccan Arabic. A two-way ANOVA was conducted to assess whether such differences in alignment were significant. There was a significant main effect of syllable type $F(1, 147)=29.610$,

p<.0001) and dialect F(1, 147)=3.697, p=.027). The interaction between the two factors was significant F(1, 147) =10.992, p<.0001). ANOVAs were conducted separately for each group to see if alignment of F0 peak varies with syllable type. Results revealed a significant main effect of syllable type for the Moroccans, F(1,98)=23.824, p<.0001, but not for the Kuwaitis, F(1,98) =1.454, p<.231, nor for the Yemenis, F(1,98)=.016, p=.900. The fact that values of F0max-to-C1 vary according to syllable structure in Moroccan Arabic makes C1 (the end of the vowel) an unlikely candidate for segmental anchoring in this language. Some kind of segmental anchoring to C1 can be applicable to Yemeni Arabic and Kuwaiti Arabic as peak F0 values in these two Arabic varieties are synchronized within the boundaries of the stressed vowel.

3.2. Segment duration

In order to see if segment duration affects peak alignment, we report in Table 2 mean duration values of three segments that are relevant to the test syllables: stressed vowel (V0-to-C1), onset consonant (C0-to-V0) and postvocalic consonant (C1-to-V1).

Table 2: Mean segment durations in ms as a function of syllable type and dialect.

	Stressed Vowel		Onset Consonant		Postvocalic Consonant	
	CV:C	CV:	CV:C	CV:	CV:C	CV:
Moroccan	108	88	75	70	55	52
Kuwaiti	131	132	61	57	68	55
Yemeni	108	105	50	49	50	49

Table 2 shows that vowel duration differs according to syllable structure only for the Moroccans. The mean duration of the stressed vowel in CV:C is 108 ms, and 88 ms in CV:. The overall analysis showed a significant effect of phonetic duration, F(1,98)=39.83, p<.0001. For the Kuwaitis and for the Yemenis, vowel duration does not vary with syllable type (F's <1.4). In general, the duration of the onset consonant and of the postvocalic consonant is longer in CV:C than CV: for the three groups of speakers. The difference is not significant (F's <1) except in one case where the Kuwaitis exhibit significantly longer duration for postvocalic consonant (67 ms *vs.* 55 ms): F(1,98)=7.97, p<0.05. Such duration difference might explain the earlier alignment in Kuwaiti Arabic for vowels in [CV:C], an effect which could be linked to the extra time made available by the longer postvocalic consonant. On the contrary, the earlier alignment in Moroccan Arabic for vowels in [CV:C] could be linked to the significant phonetic vowel lengthening in such syllables.

4. DISCUSSION

The phonetic vowel lengthening based on syllable type shown only for Moroccan Arabic is well-known [4, 21]. In Moroccan Arabic, vocalic quantity does not have a phonological status as in Kuwaiti Arabic or Yemeni Arabic: there is no phonological contrast between short and long vowels. Hence, the temporal contrast between short and long vowels is realized by the prosody in Moroccan Arabic. Findings of this study seem to indicate that in Moroccan Arabic and Kuwaiti Arabic, the effect of syllable type on F0 peak alignment can be predicted by a durational account rather than by a structural account. The durational account is based on a time-pressure explanation, according to which the F0 movement needs a determined amount of time that cannot be fully realized in a phonetically short vowel. The structural account predicts that the F0 valley and the F0 peak would be aligned to fixed segmental anchors, cf. [17]. In order to evaluate the above hypotheses, we ran separate Pearson or Spearman correlations for each group of speakers (we used the non-parametric test when distribution was skewed). If the durational account is true, there should be no co-variation in rise time and syllable duration. The results are as follows: For the Moroccans, Pearson r = 0.465, p<.01, for the Yemenis, Spearman r = 0.518, p<.01, and for the Kuwaitis, Pearson r = 0.198, p =0.169. So it appears that the idea of a fixed rise time on which the durational account is based can only account for the Kuwaiti data as it seems that rise time varies with syllable duration for the Yemenis and the Moroccans, but not for the Kuwaitis. Another plausible account that is claimed in the literature is the constant slope hypothesis [2], which predicts that the degree of F0 excursions (rise size) correlates with rise duration. To test this hypothesis, we computed the F0 change between F0min and F0max in semitones (st) for each speaker. The mean rise size is 3.01 st for the Kuwaitis, 4.74 st for the Yemenis, and 5.05 st for the Moroccans. The degree of F0 excursion is comparable for the Moroccans and for the Yemenis, whereas it is much lower for the Kuwaitis. If the constant slope hypothesis is true,

there should be a high correlation between rise size and rise duration. The results are as follows: For the Moroccans, Pearson r =.601, p < .01, for the Yemenis, Pearson r =.187, p=.62, and for the Kuwaitis, Spearman r =.231, p =.17. Unlike the Kuwaitis and the Yemenis, the Moroccans show a clear correlation between rise size and rise duration. Therefore the fixed slope hypothsis is compatible only with Moroccan Arabic data.

To conclude, the present study showed that the details of alignment patterns can vary across Arabic varieties. On the one hand, values of the F0 valley differed significantly, with Moroccan Arabic showing a later synchronization than Kuwaiti Arabic and Yemeni Arabic, which both have comparable F0 valley alignment. On the other hand, there was variation as to the effect of syllable structure on F0 peaks. The effect is not significant in Yemeni Arabic and Kuwaiti Arabic as the F0 peak is aligned within the stressed vowel in both CV: and CV:C. In Moroccan Arabic, however, the effect of syllable structure is significant: the F0 peak is found to be earlier in closed syllables than open syllables. The present paper replicates the experiments reported in [20, 21], which showed a comparable difference in vowel duration and peak alignment for closed *vs*. open syllables in Moroccan Arabic. However, the peak for open syllables is earlier here, as one might expect given that the target syllables are not under contrastive focus. For words under contrastive focus, similar differences in F0 alignment across the three Arabic dialects are also reported in [22]. Cross-dialectal variation in F0 alignment such as the one found here has also been reported for two varieties of German [3] and English [15], where it was shown that alignment of both F0 valley and F0 peak are slightly different. Cross-dialectal variation has been interpreted as a phonetic realization of the same phonological category assuming that dialects share the same accentual rise and that there is a cross-linguistic continuum of values [3, 15]. A different account analyses such continuum in terms of the notion of "secondary association" [8, 9]. Determining the implication of cross-dialectal variation in F0 alignment in relation to these two accounts is beyond the scope of this paper.

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