

# STRESS, PHONOLOGICAL FOCUS, QUANTITY, AND VOICING EFFECTS ON VOWEL DURATION IN AMMANI ARABIC

Bushra Adnan Zawaydeh and Kenneth de Jong  
*Indiana University*

## ABSTRACT

This paper examines vowel duration interactions between quantity, voicing of a neighboring obstruent, and stress in Arabic. We found that quantity effects are the strongest, while voicing effects are the weakest. Stress interacts with quantity, such that long vowels are lengthened more with stress, but stress and voicing do not interact consistently. Similarly, phonological focus on voicing contrasts has no effect on voicing lengthening, while phonological focus on quantity contrasts showed a trend towards expanding quantity differences. These results suggest that quantity lengthening is phonologically salient, while voicing lengthening is not. Also, focus and stress, while similar are not entirely identical in phonetic effect.

## 1. INTRODUCTION

This paper investigates vowel duration interactions between quantity, voicing of a neighboring obstruent, and stress in Ammani-Jordanian Arabic. Previous studies [1, 2, 3, 4, 5, 6] have found various of the three factors to induce lengthening of a vowel. Mitleb [2] found that long Arabic vowels are 65% longer than short Arabic vowels. Port et al [1] found that voiced consonants in English induce lengthening of a preceding vowel, while voiced consonants in Arabic did not do so as consistently. Similarly, Mitleb [3] found no significant durational effect of the voicing of the consonant on the duration of the preceding vowel in Arabic. These results, along with differences in the amount of voicing in English and Arabic fricatives led him to conclude that in English, unlike Arabic, the voicing contrast is not just a voicing contrast, as it is in Arabic, but also critically involves vowel lengthening. Finally, de Jong and Zawaydeh [5, 6] found that, just as in English, stressed syllables in Arabic are significantly longer than unstressed syllables, though the size of the effect seems to be somewhat smaller.

In addition to phonetic differences, one also can identify differences in the phonological uses of these durational differences. In Arabic, quantity lengthening in both consonants and vowels is the primary basis for a contrast. Following are minimal pairs that illustrate quantity contrasts:

ʔali	a man's name	ʔaali	"high"
hibbi	"you (f.) love"	hibi	"he crawled"

In comparison to quantity, voicing lengthening is not phonemic in Arabic. In fact, it might not be phonologically specified at all [3]. Finally, stress location is not, strictly speaking, phonemic in Arabic, but rather is predictable by rule. This differs from English as well, in that English stress location varies depending on lexical and morphological classes, and is often placed at unpredictable locations within a word. For both English and Arabic, stress also differs from quantity and voicing in that stress is the expression of

headedness of a syllable at a word level [5, 6], and hence is likely used for the purpose of parsing an utterance into phonological words.

Stress has been described as the localized expansion of the articulation of phonological contrasts (hyperarticulation) [7]. In hyperarticulate speech, as opposed to hypoarticulate speech, the distinctiveness of speech output is preserved. The goal in hyperarticulate speech is to communicate phonemic contrast. In de Jong's [7] view "the hyperarticulation account predicts that all the phonemically distinctive contrasts will be directly affected by stress" (p. 493). Hence, "stress can act as a diagnostic for determining the content of the linguistic code of a particular language" (p. 502).

In keeping with this description, stress has been found to have different effects on vowel duration differences [8]. In English stressed syllables, the difference in duration between vowels before voiced obstruents and voiceless obstruents is greater than it is in unstressed syllables. The same is not true with regards to the other durational effects such as compensatory shortening. These results can be explained by saying that while voicing in English is phonemic, compensatory shortening is not. Compensatory shortening before a consonant cluster is a motor strategy in speech production, not part of the linguistic code of English.

These studies, then, raise a question with respect to Arabic. Is there an interaction between stress and the two durational lengthenings (vowel quantity and voicing)? Since vowel quantity in Arabic is phonemic, there should be an interaction between quantity and stress. By contrast, since voicing in Arabic seems not to be phonologically specified, there should not be an interaction between voicing and stress.

The current study also asked a similar question concerning focus. Similar to the effects of stress on phonological contrasts, speakers may be able to hyperarticulate particular phonological contrasts in conditions which focus their attention on the contrast [9]. van Heuven has suggested that stress can be a property of the segment, rather than the syllable or the word. Similarly, it seems possible that hyperarticulation could not just be a property of a segment, but of a particular phonological contrast. If this is true, we would expect to find that in Arabic, since quantity is phonological, focusing their attention to a contrast in vowel quantity should exaggerate duration differences. In comparison, since duration differences due to voicing are not phonologically specified in Arabic, focusing on the voicing contrast vowels should not exaggerate duration differences in the preceding vowel.

To address these questions, a two-stage experiment was conducted to examine the interaction between stress and the two durational effects: quantity and voicing, and also the interaction between focus and the same two durational effects.

## 2. METHODS

### 2.1. Subjects

Four native speakers of Ammani-Jordanian Arabic participated in the experiment. Two were males (M1 and M2) and two were females (F1 and F2). Their ages ranged from 17 to 28 years old. All of the speakers were multi-lingual; however, only Arabic was used at the time of the recording, and the experimenter and the subjects consistently conversed in Arabic. Hence, any interlanguage effects in the speakers' productions are expected to be part of the urban dialect of Arabic shared by the experimenter and the subjects.

### 2.2. Materials

The first stage of the experiment involved reading a corpus of words in isolation and in two sentence contexts. The second stage involved reading the same corpus in miniature discourses that focused subjects' attention on a particular phonological contrast. Stimuli were presented in Arabic script.

Each word had one of four target syllables in initial position, as given in Table 1. These four target syllable types were either stressed or unstressed. Hence, the total number of words in isolation was eight. Table 2 shows the target syllable, the Arabic words that were used, and their gloss. (Stress is indicated there by upper-case.)

	Voiced	Voiceless
Short	bad	bat
Long	baad	baat

Table 1. Target syllables.

Target	Word	Gloss
BAD	BADawi	bedouin
BAT	BAtale	petal
BAAD	BAAdiye	desert
BAAT	BAAtiren	sharp edged
bad	baDARes	I teach
bat	baTANneh	I will be stubborn
baad	baaDILna	he extinguished for us
baat	baaTILna	what we got left
BAAT	BAAta	he stayed overnight
BAAD	BAAda	he extinguished
BAD	BAda	he started
baad	baaDIRna	our initiative
bad	baDIRna	our full moon

Table 2. Target words.

Because of peculiarities in some of the speakers' production of the words in the isolation condition, only the words in sentential frames were included in the analysis. The two sentential frames were as given below:

1. Post-nuclear frame: In this case the target word was not focused on. The sentential focus appeared on the word “ʔana”. The frame that was used was:

ʔana ʔult \_\_\_\_ mish huwwe      “I said \_\_\_\_ not him.”

2. Semantic focus: Each of the eight words were placed in a sentence that contrasted the target word with another word semantically, not structurally. For example:

ʔana ʔult badawi mish fallah      “I said badouin not peasant.”

After recording the first stage, a subset of the words were produced in conditions which focused speakers' attention on either quantity or the voicing contrast, as shown in Table 3.

Voicing	baat	baad
Quantity	baad	bad

Table 3. Phonological focus types.

As in stage 1, these syllable types were placed in stressed and unstressed positions, and the words were placed in a sentential frame. The target word was matched with another word that minimally differed from it either in its voicing ([d] or [t] for the second consonant), or the quantity of the vowel (long or short). An example is:

ʔana ʔult baata mish baada      “I said he stayed overnight not he extinguished.”

ʔana ʔult baada mish bada      “I said he extinguished not he started”

The subjects' voices were recorded on a Marantz cassette recorder, and later analyzed using Soundscope on a Macintosh. Vowel durations of the target syllables were measured from 300 Hz bandwidth spectrograms.

### 2.3. Hypotheses

Four factors are controlled in the experiment, 1) consonant voicing, 2) vowel quantity, 3) stress, and 4) prosodic/focus position. Concerning the last set of factors, we have effective comparisons between focused and accented versus unfocused and unaccented (the two frames used in stage one), and between semantically based focus (from stage one), and phonological focus (from stage two). We expect that the vowel quantity, stress, and voicing all affect vowel duration. In addition, we expect an interaction between stress and quantity such that quantity differences are greater with stress, but no interaction between stress and voicing. Concerning differences in focus, we expect larger differences in quantity with focus and accent than without (the two frames in stage 1). Based on previous results with phonological focus [9], we would expect the same sort of increase with phonological focus on quantity.

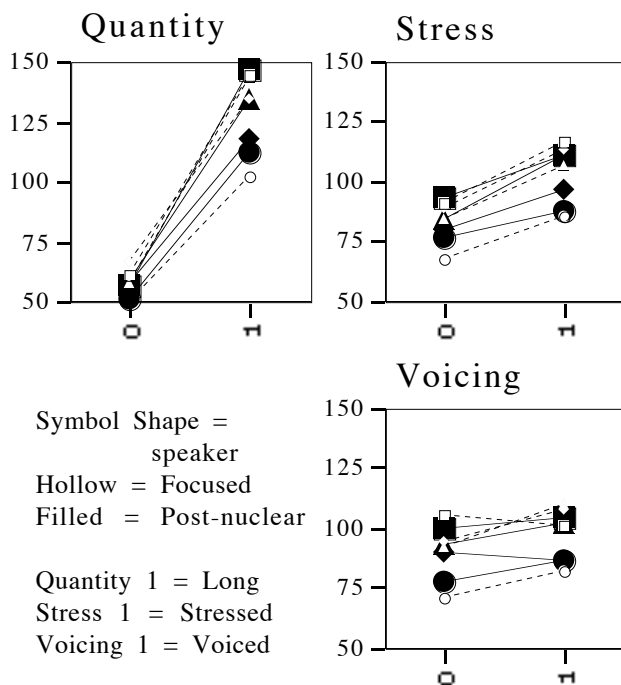
To statistically examine these results, we submitted duration and formant measurements from various portions of the dataset to multi-way ANOVA's which included subject as a fixed factor. Thus, statistical results for the current study only support our analysis of the particular speakers examined here, and generalizations to the Arabic community can only be made with caution.

## 3. RESULTS

Duration measurements from the Semantic Focus and Post-nuclear frames were submitted to separate four way ANOVA's with voicing, stress, quantity, and subject as factors. In the focus condition, stress, quantity, and voicing affected vowel durations. Stressed vowels are significantly longer than

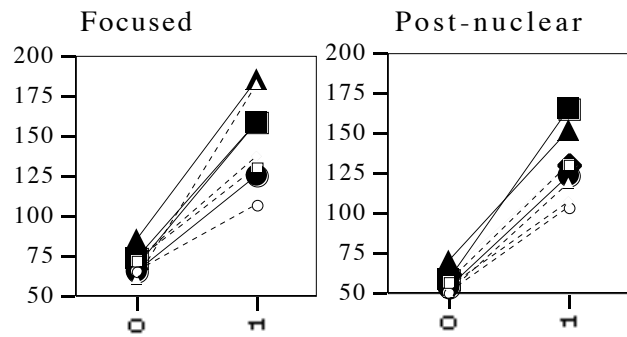
unstressed vowels ( $F(1, 96) = 77.409, p < 0.0001$ ); long vowels are significantly longer than short vowels ( $F(1, 96) = 862.705, p < .0001$ ); and voiced consonants significantly lengthen previous vowels ( $F(1, 96) = 15.077, p < 0.0002$ ). The significant effect of voiced consonants is particularly interesting, since some previous studies in Arabic found no such effect in Arabic. A similar analysis of the Post-nuclear data yielded slightly different results. Here, quantity and stress have significant effects: (for stress  $F(1, 96) = 52.934, p < 0.0001$ , and for quantity  $F(1, 96) = 864.538, p < 0.0001$ ); however, the effect of voicing is not significant.

Figure 1 illustrates the various effects, and indicates some differences between them. First, the quantity difference is by far the largest of the three. With focus, the stress effect and the voicing effect are not terribly different in size. However, the voicing effect does not appear in post-nuclear position.



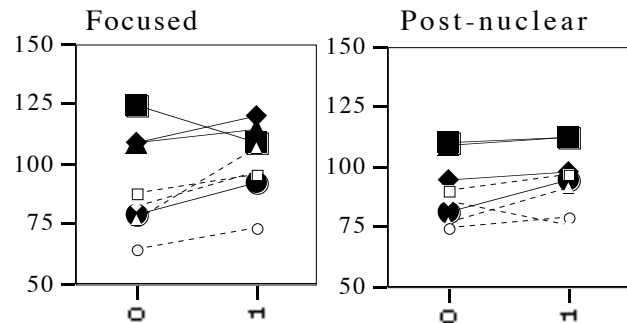
**Figure 1.** Average vowel duration differences due to quantity, stress, and voicing for each speaker in the focused and post-nuclear conditions.

Our analyses of this data also found significant interactions between stress and other factors. In both conditions, stress interacts with quantity (post-nuclear:  $F(1, 96) = 16.2, p < 0.0001$ ; focus:  $F(1, 96) = 9.673, p < 0.0025$ ). This is shown in Figure 2. Long vowels get much longer when they are stressed than short vowels when they are stressed. Thus, stress results in expansion and also extra lengthening on the long vowels.



**Figure 2.** Average vowel duration differences due to quantity. Filled symbols indicate stressed syllables. Shape indicates different subjects. 1=long.

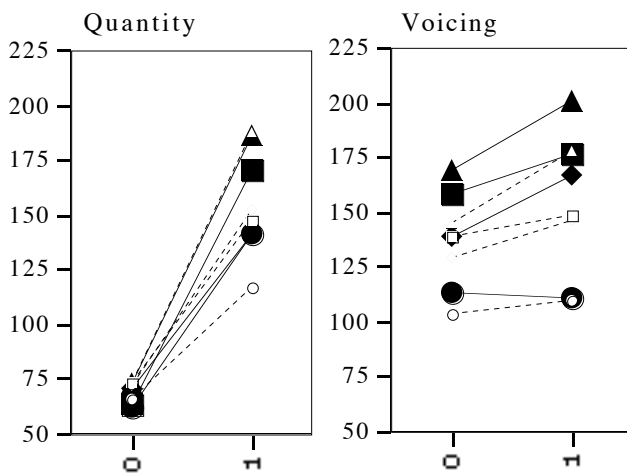
In the post-nuclear condition, there was, however, no significant interaction between stress and voicing. In the focus condition, stress did interact with voicing ( $F(1, 96) = 6.197, p < 0.0145$ ), as is shown in Figure 3. Here, however, the direction of interaction is the opposite of what is found in the quantity interactions; voiced lengthening is greater in unstressed syllables.



**Figure 3.** Average vowel duration due to voicing. Filled symbols indicate stressed vowels. 1=voiced.

To examine the effect of different kinds of focus, we separated data elicited with focus on voicing from that elicited with focus on quantity, paired it with the same types from the semantic focus condition and submitted each set to a four-way ANOVA with voicing or quantity, stress, condition (phonological or semantic focus), and speaker as factors.

Considering the voicing corpus in more detail, main effects were found for voicing and stress, as well as for focus condition (voicing,  $F(1,96) = 27.377, p < 0.0001$ ; stress,  $F(1,96) = 130.056, p < 0.0001$ ; condition,  $F(1,96) = 24.653, p < 0.0001$ ). These effects are illustrated in Figure 4. Phonologically focused vowels were longer overall than semantically focused vowels. As with the analysis reported above, stress interactions with voicing were inconsistent across subjects, and hence were not significant ( $F(1,96) = 1.735, p > 0.05$ ). More to the point, phonological focus did not interact with voicing, either ( $F(1,96) = 0.150, p > 0.05$ ). Thus, both stress and focus manipulations suggest that vowel duration differences due to voicing are not phonologically salient in the Arabic speech of these subjects.



**Figure 4.** Quantity and voicing effects on vowel duration. Filled symbols indicate phonological focus.

Quantity behaves somewhat differently. Results are illustrated in the left panel of Figure 4. As in the analysis of quantity reported above, long vowels are very much longer on average than short vowels, a difference of approximately 100 ms. Stress also significantly lengthened vowels ( $F(1,96) = 12.635, p < 0.0006$ ). However, unlike in the voicing corpus, there is no main effect of condition ( $F(1,96) = 0.620, p > 0.05$ ). Also as in the previous analysis, stress and quantity interact, such that quantity differences are larger in stressed syllables ( $F(1,96) = 6.009, p < 0.016$ ). Examining the quantity by condition interaction reveals a difference between the effect of focus and that of stress. There is a trend toward an interaction ( $F(1,96) = 3.311, p < 0.072$ ) whereby not only is the difference between long and short vowels greater with phonological focus, but, unlike the effect of stress, focused short vowels actually get shorter, as is indicated by the crossing of dashed and solid lines in the left panel of Figure 4. Hence stress both increased duration and increased duration differences; phonological focus merely increased differences.

#### 4. DISCUSSION AND CONCLUSION

All three lengthening effects (stress, quantity, and voicing) were detected in the Arabic speakers' productions. However, it is quite clear that all three durational effects are quite different. The first two, stress and quantity, differ greatly in magnitude. Differences due to quantity averaged from 75 to 100 ms, while stress-related differences were less than a third the magnitude. The last effect, voicing, differs from the former two in consistency. In post-nuclear position, the effect of voicing is weak enough to be completely obscured.

This inconsistency is one piece of evidence that the voicing effect is not phonologically salient. A second piece of evidence for this conclusion is the lack of any consistent effect of stress on the magnitude of the voicing effect. This contrasts with the results for English where the voicing effect is considerably larger with stress [8]. Similarly, overt focus on the voicing contrast has no effect of increasing the size of the voicing difference in duration of the vowel.

A second set of conclusions can be drawn concerning the effect of stress. The fact that stress increases quantity distinctions suggests that it is profitable to view stress effects

as hyperarticulation. The selectivity of such interactions, namely that voicing lengthening is not also enhanced in a language in which this effect is said to not be phonemic, lends further support to the same conclusion.

However, stress is not simply hyperarticulation. The difference between the two can be seen by comparing the stress effects and the effect of overtly having speakers focus on a particular linguistic contrast, as in the 'phonological focus' condition. Both stress and overt focus increase specified durational contrasts (quantity), and both stress and overt focus fail to increase non phonological duration contrasts (voicing). The difference between the two is that stress also consistently creates lengthening, while focus might not. Thus, stressed short vowels become longer because they are stressed (though not as much longer as if they were long vowels); focused short vowels do not become longer. It is tempting to speculate that this difference between focus and stress is due to a dual role of stress within a phonological system that has been pointed out elsewhere [10]. Stress not only indicates the location of contrasts which are particularly salient, but also acts as a prosodic feature, marking the occurrence of a prosodic word. Hence stress is not just indicating other contrasts to be communicated, but is itself a syntagmatically important element. Durational lengthening is, then, an indicator of stress occurrence.

#### ACKNOWLEDGEMENTS

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