ACOUSTIC CORRELATES OF EMPHASIS IN ARABIC

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ABSTRACT

The effects of emphasis, a secondary articulation in the posterior vocal tract, were investigated in the speech of 8 speakers of Jordanian Arabic. A number of acoustic parameters were measured in the consonants and vowels of mono- and bisyllabic minimal pairs containing plain or emphatic consonants in initial, medial, or final position. In general, the acoustic correlates of emphasis include a raised F1, lowered F2, and raised F3 in the vowel adjacent to the emphatic consonant. This pattern across the three formants suggests that emphasis involves a constriction near the epiglottis. In addition, the present results indicate that the spectral mean of the consonant itself is also a reliable acoustic correlate of emphasis. However, while the spread of emphasis can be detected throughout both vowels of bisyllabic words, only the target consonants themselves (not the surrounding consonants) show an effect of emphasis.

Keywords: emphasis, pharyngeals, Arabic.

1. INTRODUCTION

Emphasis is a distinctive feature of Semitic languages such as Arabic and Hebrew. The term 'emphasis' refers to consonants produced with a secondary constriction in the posterior vocal tract and a primary constriction typically in the dental/alveolar region. Classical Arabic included four emphatic coronal obstruents /dˤ, tˤ, ðˤ, sˤ/ and their plain (non-emphatic) counterparts /d, t, ð, s/. Today, many dialects still retain these four distinctions. Most, if not all, dialects of Arabic are characterized by emphasis, and have minimal word pairs that differ only in the presence of a plain versus an emphatic consonant.

While linguists consider consonants as the primary locus of emphasis and speak of emphatic consonants, most acoustic analyses of emphasis have focused on properties of the vowels surrounding the emphatic consonant rather than the consonant itself. In all dialects of Arabic that have been investigated, emphasis is consistently manifested by a lowering of F2 of the vowel following the emphatic consonant (e.g., [4, 8]). While emphasis clearly lowers F2 of the following vowel, its effect seems to be modified by vowel quality. As observed by Alioua [2], Card [4], and Yeou [7], the effect of emphasis (F2 lowering as measured at vowel midpoint) differs for the vowels /i/, /u/, and /æ/. The greatest lowering occurs for the low front vowel /æ/. In fact, F2 lowering for /æ/ results in a vowel with a distinctly different quality. The low back vowel /ɑ/ occurs as an allophone of the low front vowel /æ/ only in an emphatic context. F2 lowering is less for the vowels /i/ and /u/, with a slightly greater lowering for /i/ than /u/ (e.g., [2, 4]). All dialects of Arabic distinguish long and short vowels. F2 differences between vowels following plain and emphatic stops have been shown to be greater for short vowels as compared to their long counterparts when measured at the midpoint of the vowel (e.g., [4, 6]).

While vowel F2 has received most attention, the patterning of F1 and F3 may provide important information about the exact location of the posterior constriction. Specifically, while a pharyngeal or uvular constriction both result in a low F2 and a high F1, vocal tract modeling studies suggest that F2 would be lower for uvulars while F1 would be less high for a uvular constriction relative to a pharyngeal one. In addition, pharyngeals have a lower F3 [3]. However, only a few studies have critically included F1 or F3 measures. Of those studies, Alioua [2] and Yeou [7] show a rise in F1 while Card [4] and Norlin [6] report no effect of emphasis on F1 or F3.

Acoustic properties of emphatic consonants have received scant attention in the literature. In her investigation of Jerusalem Arabic, Card [4] reports F2 values taken from spectrograms but it is not clear at which point (release burst, onset, or offset of the formant transition) these measurements were taken. Her data suggest that F2 in emphatic consonants is lower than in their plain counterparts.

The present study explores the acoustic correlates of emphasis by measuring a number of acoustic parameters in both emphatic consonants and their surrounding vowels. Specifically, spectral moments were measured for the consonants and F1, F2, and F3 were measured at the onset, midpoint, and offset of the vowels. Emphasis is typically claimed to spread from the emphatic consonant to neighboring sounds. While previous studies have shown that F2 of the following or preceding vowel usually is affected by emphasis, it is less clear whether intervening consonants are also modified. Measurements of the consonants and at multiple locations in the vowel may provide a more fine-grained account of the spread of emphasis and the roles of vowel length and vowel quality in this process.

2. EXPERIMENT

By reason of notorious dialectal variability, this study focused on a single dialect of Arabic, namely Jordanian Arabic, spoken in the Irbid region of Jordan. This dialect is spoken by approximately a million people residing in the northern areas of Jordan, including Irbid, Ajloun, Jerash, and the many villages around these cities.

2.1 Stimulus materials

The four emphatics of Jordanian Arabic /dˤ, tˤ, ðˤ, sˤ/ and their plain (non-emphatic) counterparts /d, t, ð, s/ were recorded in target word pairs in the carrier phrase [ʕɪħki_____ kəmæn məɹɛh] ("Say ____ once more") to control for context effects. The stimuli were printed on notecards in Arabic script. Stimuli consisted of mono- and bisyllabic words and nonwords with the target consonant in word-initial, word-medial, and word-final positions. In the Arabic script, emphatics are realized by a different orthographic symbol, so native speakers were able to produce nonwords with both emphatic and plain consonants. The vowels /iː, i, æː, æ, uː, u/ were included as target vowels. Each stimulus was repeated three times.

2.2 Subjects

Eight speakers (4 females and 4 males) were recorded. All were native speakers of the Irbid dialect of Jordanian Arabic with no known history of either speech or hearing impairment.

2.3 Recordings

Speakers were recorded in a quiet room in the Department of English Language and Literature at the University of Jordan using a high-quality microphone (ElectroVoice N/D767a) and digital solid-state recorder (Marantz PMD 671). Sampling rate was 22 kHz with 16-bit quantization.

2.4 Measurements

All measurements were made with Praat speech analysis software. *Formant frequency measures* (F1-F3) were taken from LPC spectra calculated over a 20-ms Hamming window at the beginning, middle, and end of the vowel. *Spectral moments* were computed for obstruents following the procedures described in [5]. For fricatives, a DFT was calculated using a 20-ms full Hamming window in the middle of the frication noise. For stops, this window was centered over the burst. In addition, for all obstruents, a window was centered over the boundary between consonant and vowel. Briefly, each DFT was treated as a random probability distribution from which the first four moments (mean, variance, skewness, and kurtosis) were computed.

3. RESULTS

3.1. Monosyllables

Effects of emphasis were most obvious in the vowel. Specifically, as shown in Figures 1 and 2, vowels adjacent to an emphatic consonant had a consistently higher F1, lower F2, and higher F3 than vowels adjacent to plain consonants. This was true for both short and long vowels. Vowel quality affected the extent of F2 lowering, with /æ/ having the greatest amount of lowering and /u/ having the least. The effect of the emphatic consonant was usually most pronounced immediately adjacent to the consonant and decreased at measuring points further away from the consonant.

Consonantal measures were more variable. However, the first moment (spectral mean) was significantly lower for emphatic consonants. This lowering was on the order of 100-200 Hz for both initial and final emphatic consonants.

Figure 1: Formant frequency values (F1 in top panel, F2 in middle panel, F3 in bottom panel) measured at onset, middle, and offset of the vowel in CVC words with the target consonant (plain vs. emphatic) in **word-initial** position.

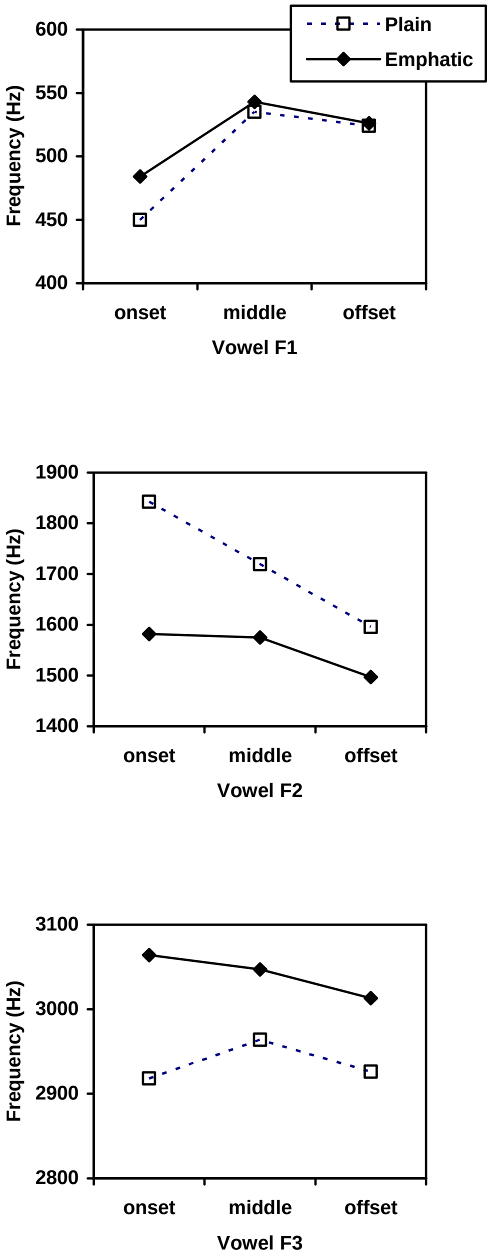
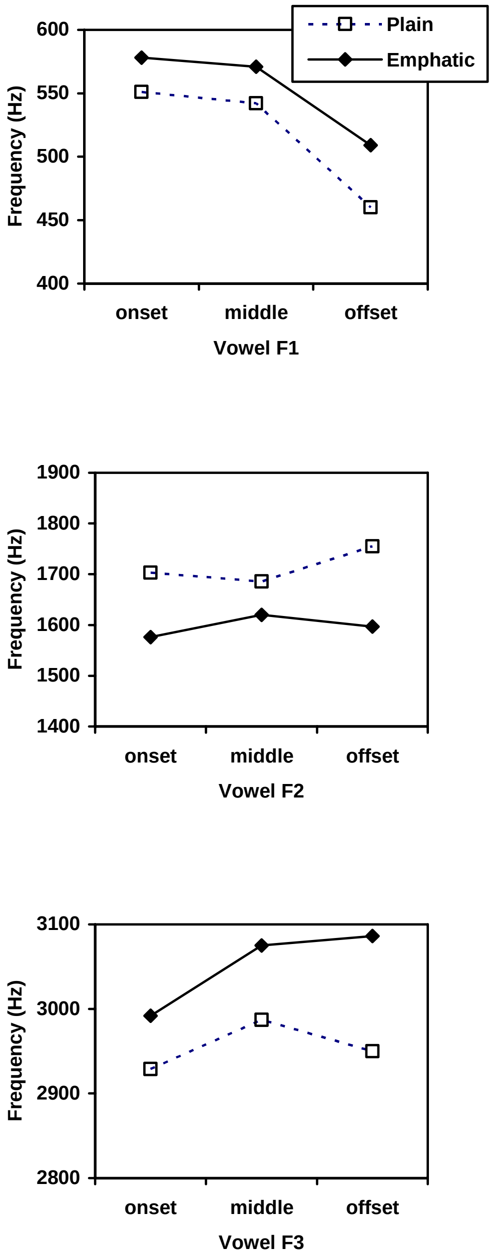


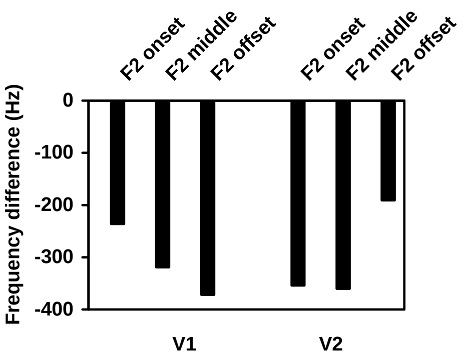
Figure 2: Formant frequency values (F1 in top panel, F2 in middle panel, F3 in bottom panel) measured at onset, middle, and offset of the vowel in CVC words with the target consonant (plain vs. emphatic) in **word-final** position.



3.2. Disyllables

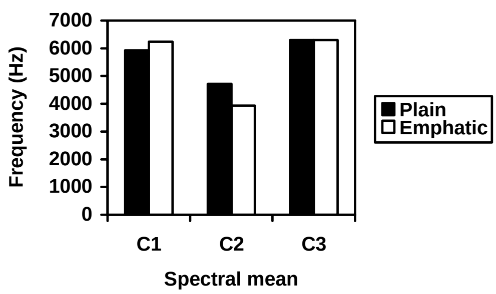
The disyllables with target consonants in initial and final position showed effects very similar to those described for the monosyllables. In general, the vowel formants were most affected close to the target consonant but the influence of the emphatic consonant persisted throughout the entire word. For reasons of space, we will focus on disyllabic words in medial position which allows for a direct comparison of rightward and leftward spread of emphasis. Figure 3 shows the difference between F2 in plain and emphatic environments.

Figure 3: Second formant frequency differences (plain – emphatic) measured at onset, middle, and offset of the vowels in CV_1CV_2C words with the target consonant (plain vs. emphatic) in medial position.



Measurements for the consonants indicated that while emphasis again resulted in a significant lowering of the spectral mean of the target consonant itself, no such effect could be detected in either the initial or final consonants (see Figure 4).

Figure 4: Spectral mean for the three consonants in $C_1VC_2VC_3$ words with the target consonant (plain vs. emphatic) in medial position.



4. CONCLUSIONS

In general, the acoustic correlates of emphasis include a raised F1, lowered F2, and raised F3. This pattern across the three formants suggests that emphasis involves a constriction near the epiglottis, consistent with the xeroradiographic data that indicate a narrowing at the level of the third and second cervical vertebrae [1]. In addition, the present results indicate that the spectral mean is also a reliable acoustic correlate of emphasis. However, while the spread of emphasis can be detected throughout both vowels of bisyllabic words, in terms of consonants, only the target consonants themselves show an effect of emphasis.

Future research will explore the extent to which perception of emphasis is based on information in the vowels, consonants, or both.

5. ACKNOWLEDGMENTS

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