UVULARIZATION SPREAD IN ARABIC*

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This paper examines the localization of contrasts in the ulvularized quality in the speech of Ammani Jordanian Arabic. Phonological analyses have noted that certain coronal consonants, traditionally called 'emphatics', are accompanied by an uvularized quality to vowels located in various parts of the word in which they appear. This paper reports three experiments which examine the degree to which this uvularized quality is reflected in various vocalic positions with respect to the triggering consonant. These experiments find the greatest amount of uvularization on the vowel following the triggering consonants, somewhat less uvularization in vowels which precede the trigger by at least three syllables, and somewhat less uvularization in vowels which appear more than two vowels after the trigger. All of these vowels are significantly different from those in words without an emphatic trigger. In addition, the effects of various high segments on the spreading of the uvularized quality were also examined, finding that the presence of high segments does not affect the occurrence of uvularization distant from the emphatic trigger. Finally, uvular stops also trigger a weaker variety of uvularization more than one syllable away from the stop.

1 Introduction

This paper examines how contrasts involving uvularization are expressed by speakers of the Ammani Jordanian dialect of Arabic. Specifically, it examines the subgroup of the gutturals (the emphatics and the uvulars) which both involve a retracted tongue backing gesture which acoustically has the effect of lowering the second formant. The literature on Arabic uvularization is replete with observations that this depression of the second formant due to uvularization appears in various locations in the word, some of which are quite distant from the consonant which is specified for uvularization. Such observations have lead a number of phonologists to posit spreading analyses of uvularization.

Based on the physiological work by Ghazeli (1977), and Zawaydeh (1999), we refer to the effects of emphatic consonants as uvularization. Ghazeli (1977) took cineflurographic films of himself articulating emphatic consonants, and found that the greatest constriction in the pharynx during the articulation of emphatic consonants is at the height of the second vertebra. Acoustic analyses of his speech showed that this constriction in the uvular region has a particularly marked lowering affect on F2, especially for low vowels. Zawaydeh (1999) examined images obtained with an optical endoscope, and also found approximation of the tongue back in the upper part of the pharynx.

1.1 Previous Studies of Uvularlization Spread

Younes (1982) spectrographically investigated a dialect of one elderly male from the northern part of the West Bank, which he calls Palestinian Rural Arabic. In addition, Younes also recorded his own speech. He examined the long distance effect of emphatic consonants on low vowels, and found that

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the closer a vowel is to an emphatic sound, the lower its F2 will be. Hence, anything that creates temporal distance from the trigger (the presence of long vowels and additional segments) allows less uvularization to be exhibited. In addition, word boundaries and some morphemes (such as "la" and "ma") weaken emphasis. Ghazeli (1977: 114) also noted an effect of eliminating uvularization spread.

In addition, Younes found that the front vowels /ee/ and /ii/ are not affected as much as the low vowels by emphasis. Moreover, as Herzallah (1990)'s phonological analysis of Younes' study notes, in the case of the low vowel, there is a clear perceptual distinction between the emphatic vs. non-emphatic low vowel. By comparison, although the non-low vowels sound "darker" or "louder," they do not have distinct readily recognizable vocalic qualities which could be recognized by the native speakers of Arabic (p. 69). Herzallah also noted two more aspects of the spreading phenomenon. The first, based apparently on impressionistic observation, notes that high segments seem to block the spread of uvularization. The second, based on Younes' instrumental work on single tokens, reports that a low vowel following an [n] or an [l] (which do not have any pharyngeal specification) are not uvularized when there is a uvularized segment at the beginning of the word.

Davis (1993, 1995) impressionistically found similar patterns in a male speaker of Southern Palestinian Arabic. Leftward (anticipatory) uvularization extends to a preceding word boundary, regardless of whether a high segment intervenes. In comparison, rightward (perseveratory) uvularization is blocked by segments with a palatal articulation.

The main goal of Shahin (1997a, b) was to show that in Abu Shusha Palestinian Arabic, there are two kinds of harmonies. One is what she calls pharyngealization harmony, and the other is uvularization harmony. Here, gutturals trigger pharyngealization harmony, while emphatic (secondarily uvularlized) consonants, as well as the modern reflex of Classical /q/, trigger uvularization harmony. Again, acoustic analyses supported the high segment blocking patterns found in previous studies with the exception of some subtle differences in the effects of high vowels. Card (1983) examined four urban speakers, two from Jerusalem, and two from Jordan, and found similar blocking patterns as well.

Comparing these patterns to those found for various studies of speakers of other dialects reveals many similarities, with some small differences. Thus, though the details of the spreading phenomenon may be subject to variation, the existence of uvular spreading of some sort is a very robust feature of some very geographically diverse Arabic dialects. Heath's (1987) acoustic study of a speaker of Moroccan Arabic found that both emphatics and the uvular /q/ trigger uvularization which is reduced, but not eliminated, by the presence of high segments. Ghazeli, a Tunisian speaker, acoustically analyzed his own speech, and also found that anticipatory spreading is more extensive than perseveratory spreading (Ghazeli, 1977). He also found that [ii] reduces uvularization spread.

One might ask, why would uvularization spreading be such a robust phenomenon, found in such geographically diverse speakers? Uvularized segments could be considered special sounds because they are doubly articulated, and because their secondary articulation is in the back part of the vocal tract. Most languages do not have such sounds. As Ohala (1996) explains, secondary articulations are not preferred by languages of the world, because languages prefer "good" speech sounds. According to Steven's Quantal Theory of Speech, good speech sounds are sounds that can be perceived within a short period of time, which is approximately 40-50 ms., the rate at which the auditory system "is most sensitive to changes." Hence, good speech sounds involve "rapid modulations of various parameters in the acoustic signal, i.e. amplitude, periodicity, spectral shape" (p. 1721). Ohala explains that phonological contrasts such as [p], [m], or [f] have these auditory characteristics. In comparison, secondary articulations such as pharyngealization, glottalization, palatalization and labialization are not "robust" sounds auditorily. Ohala points out that they are not robust because "(a) they take a long time (up to 100 ms.) to manifest their distinctive characteristic and (b) their secondary articulations are superimposed on and thus mask some of the distinctive aspects of the primary articulation, especially the formant transitions cueing place" (p. 1721). Consequently, languages prefer having sounds that have the robust features of primary articulations.

If a language has a small inventory, the sounds will probably be sounds that have only a primary articulation. If the language has a large inventory, it may use the non-robust features of secondary articulation. Since secondary uvularized sounds are not robust sounds, and since they still need to express their phonological contrast with plain sounds, the contrast is enhanced through extending the feature [Retracted Tongue Back]. Flemming (1995) proposes that one of the ways for the preservation of contrasts is by "durational enhancement," which involves "extension in the duration of an auditory feature" (p. 52). Flemming adds that there are two possible motivations for the extension of an auditory feature durationally. One motivation is that it would make it easier for the listener to perceive. In the case of Arabic, enhancing the uvularization feature by extending it durationally would enhance the distinctiveness of contrast between a secondary uvularized segment and a plain segment. The second motivation for the extension of the feature is that it would be "easier for the articulator to remain in the same position than for it to move" (p. 53-54). In the case of the Arabic emphatics, this would indicate that it is easier for the back of the tongue to remain in the retraction position than to move. If it remains in the same position, one would exert less effort and at the same time enhance the contrast between a plain coronal and an emphatic. Hence, both articulatory and acoustic factors might be involved in the spreading of uvularization in Arabic.

1.2 Phonological and Phonetic Analyses of the Phenomenon

Linguists have been interested in several aspects of the uvularization phenomenon, especially what triggers uvularization, and what determines the localization of spreading. Some have claimed that uvularization is the property of the syllable; others have argued that it is a property of the vowel, and still others view uvularization as the property of specific consonants, namely the uvularized coronals. Studies that considered uvularization to be a property of the syllable are Lehn (1963), and Broselow (1976, 1979). By contrast, Card (1983), Schulte (1985), and Davis (1993, 1995), as well as the classical tradition, specify uvularization as part of a consonantal contrast on selected coronal consonants and then redundantly specify the contrast in various places in the word.

Strong evidence against the syllabic and vocalic approach rests in the fact that uvularization occurs only where there is a uvularized consonant. The only way that other consonants can be uvularized is if they are in the environment of a secondary uvularized phoneme. Thus, uvularization is not a property of the syllable, since in such an account the actual phonemic content of the syllable is irrelevant. Similarly, a uvularized vowel only occurs in words with a uvularized coronal consonant phoneme; the distribution of the uvularlized vowels is restricted to ones predictable on the basis of the location of uvularized coronal consonants. Hence, this study assumes that the uvularization is introduced as a contrastively specified aspect of certain consonants, and gets spread redundantly to various locations in the word.

Complicating this pattern somewhat are other segments that can create the effect of uvularization, specifically uvulars. Little attention has been given to the effect of these sounds. El-Dalee (1984) claims that uvulars have the effect of uvularizing an adjacent vowel. So, while the effect of the secondary uvularized coronals is spread throughout the word, the effect of the uvulars is more localized.

Conclusions from studies on Arabic dialects indicate that the uvularization spread from emphatics differs from dialect to dialect, and from researcher to researcher. While Schulte (1985) claims that in Cairene the spreading goes throughout the entire word, Davis (1995) claims that rightward (perseveratory) spreading may be blocked by the presence of high segments, while the leftward (anticipatory) spreading is not. Various others have noted that high segments seem to keep uvularization from spreading from the contrastively uvularized segment (Ghazeli 1977, Younes 1982, Card 1983, Heath 1987, Herzallah 1990, Davis 1995, Shahin 1997a, b).

Uvularization spread has long been considered to be a phonological phenomenon, and researchers have used different phonological models - generative, autosegmental, grounded phonology, and optimality theory - for accounting for its distribution. Based on impressionistic data, Broselow (1976, 1979) wrote generative rules that specified the domain of emphasis spread. Van der Hulst and Smith (1982) translated Broselow's analysis into autosegmental terms, and Card (1983) and Herzallah

(1990) extend the autosegmental analysis. Davis (1995) adopts a grounded phonology approach. Finally, McCarthy (1997) and van de Vijver (1996) examine Davis's data in an optimality theoretic analysis. Further complicating such analyses is the unresolved question as to the scope of such analyses. For example, Keating (1990) reviews the work of Ghazeli (1977) and Card (1983) and proposes that uvularization spread in Arabic is phonetic, and so, might be irrelevant for traditional phonological analyses.

We must ask, then, how to determine if uvularization spread is phonological or phonetic. There are two formal proposals concerning this. First, if uvularization spread interacts with other phonological rules, then it must be phonological. Second, if uvularization is blocked by certain segments, then we might consider it to be a phonological process.

These two formal arguments have been put forward by Alghazo (1987) and Herzallah (1990). Alghazo (1987) claims that emphasis spread is a phonological phenomenon since it interacts with other phonological processes. He states that in his dialect of Jordanian Arabic, spoken in the Ajloun mountain area of the northern part of Jordan, an emphatic consonant can be de-emphasized via an assimilation process when it is word final, and when the initial consonant of the following word is a homorganic nonemphatic consonant. Similarly, he claims that emphasis interacts with vowel rounding in the dialect of Ajlouni Jordanian Arabic, such that the rounding of certain vowels epenthesized by a phonological rule is determined by their location with respect to emphasis spreading domains. In a generative analysis, uvularization spreading, then, would formally precede the rounding rule. Herzallah (1990) similarly argued against the view that uvularization spread is phonetic, since it is constrained by some blocking segments.

In addition to formal arguments, others have proposed that the phonetic/phonological distinction can be determined experimentally. Pierrehumbert (1990), Keating (1988, 1990, 1996), and Cohn (1993) argue that phonetic representations are quantitative, while phonological representations are qualitative. Phonetics is specialized in "numbers," "on continuous dimensions" while phonology is specialized in "discrete symbolic elements" (Keating, 1996: 263). Keating offers the items in Table 1 as diagnostics for the distinction between phonology and phonetics, and reviewed a number of cases where what has been assumed to be a phonological phenomona turned out to be phonetic. Browman and Goldstein (1990) found that in a phrase such as "perfect memory", the [t] in "perfect" might not be audible, even though there are traces of the articulatory motions to produce the [t]. Thus, what a phonological approach would assume to be a categorical deletion of a segments turns out to be a gradient, and therefore phonetic, lenition process. Keating (1996:268) concludes:

> Browman and Goldstein's suggestion that the degree of overlap depends on rate or casualness of speech so that the resulting assimilation occurs more-or-less, not all-or-none. It's not simply that the spreading is optional but more likely to occur in fast speech; instead the overlap usually does occur but to different degrees in different situations, only the most extreme of which result in auditory deletion or assimilation. Phonological spreading is not generally taken to operate gradiently in this way, whereas phonetic implementation must.

Phonology	Phonetics
Symbolic representations	Physical representations
Allow idealization of temporal chunking (segmentation), qualitative categorization (labels), timelessness	Quantitative values on multiple independent dimensions; continuous in time & space
Rules manipulate features and feature values, and associations	Internal temporal structure allows overlap
Thus phonological rules can be category changing, produce static changes over whole segments; can be lexical/ cyclic	Rules interpret feature values in time and space, can be gradient

Table 1. Formal Diagnostics Distinguishing Phonological and Phonetic Phenomena.

Studies by Younes (1982) and El-Dalee (1984) have investigated the gradiency of the spreading. Each supports the view that uvularization spread is gradient, and hence phonetic in nature. El-Dalee (1984), for example, says that the spreading might depend on the rate of speech, and that it is more likely to happen in fast speech. He offers this as an indication that it is a phonetic implementation that happens gradiently, like the overlapping case of consonant clusters in English. If El-Dalee's claims are right, then uvularization spread would be similar to the phonetic overlapping case of English consonant clusters.

Zawaydeh (1997, 1998) reports pilot investigations of uvularization spread in Ammani Jordanian Arabic involving one speaker. She reports (1) that none of the high segments block spreading when the trigger is a secondary uvularized (emphatic) segment, (2) when the trigger is the uvular /q/, some blocking effects are observed, (3) the uvularization spread from the /q/ is weaker than the spread from emphatic segments, and (4) the farther away that the uvularization trigger is, the weaker are its effects on the target.

This paper examines uvularizaton spread in the speech of residents of Amman, extending previous research by including a larger subject base in an acoustic study and a more systematic examination of the different aspects of the uvularization spreading phenomenon. Previous studies examined only male speakers, while the current experiments include speakers of both sexes. Experiment 1 examines perseveratory spreading; Experiment 2 examines anticipatory spreading, and Experiment 3 examines the relative strength of spreading in the two directions.

2 Experiment 1

The first experiment investigates the issue of rightward uvularization spread from the primary emphatic consonants and from the uvular /q/. The major question pursued here is whether high segments block anticpatory uvularization spread in the dialect of Ammani-Jordanian Arabic. In previous studies, it has been claimed that high segments can block this spreading.

2.1 Subjects

Speakers in this study are three women and three men who speak the Ammani-Jordanian dialect. Each subject was born in Amman, and all but two still reside there. Their ages range from 19 and 28 years old, and all were college-educated in Jordanian universities.

2.2 Stimuli and Materials

The data are designed to elicit low vowels in various potentially uvularized and non-uvularized conditions. Target vowels occurred either internal to words with or without uvularization triggers preceding the target vowel. In addition, in order to examine potential blocking effects, an additional set of words included a high segment, [w, j, i, u, S], between the trigger and the target vowel. Because bilabial and nasal consonants lower vowel formants, they are not included in any target words. Words with /r/ were avoided since /r/, itself, might trigger uvularization spread. The lexical corpus is given in Table 2.

Blocking segment	Control (Non-uvularized)	Following an Emphatic	Following /q/
None	/dalalaat/ 'indications'	/?ad¢allaatak/ 'your muscles'	/qallalatha/ 'she lessened it'
/w/	/lawaaha/ 'he bent it'	/t¢awaaha/ 'he folded it'	/ma/aqwaha/ 'how strong she is!'
/y/	/zayyadatha/ 'she increased it'	/d¢ayaa?ak/ 'your being lost'	/qayyadatak/ 'she handcuffed you'
/i/	//ittibaa?aatak/ 'what you follow'	//it¢$ilaa?aatak/ 'your readings'	/qilaa?/ 'castles'
/u/	/sulaalaatak/ 'you ancestry'	/but¢uulaatak/ 'hour heroic deeds'	/buquulaatak/ 'your beans'
/S/	/?aSSaak/ 'he fed you dinner'	/t¢aSSat/ 'she fled'	/qaSSaatak/ 'your hay'

Table 2. Linguistic Corpus Used in Experiment 1. Target vowels are underlined. Emphatic segments are indicated by subscript dots.

Each of the 18 tokens was presented randomly three times in a list with distracter items. The subjects read the list, saying each target's number aloud. The targets were produced in isolation to avoid higher level prosodic conditions that might affect the spread of uvularization.

2.3 Analyses

Recordings were digitized on a Macintosh using Soundscope at the Indiana University Phonetics Lab. The first two formants were estimated using a 13th order LPC analysis with a 20 ms Hamming window. In the few cases where this method failed to yield an F2 value matching what was expected from inspection of a 300 Hz bandwidth spectrogram, an estimate was made directly from the spectrogram.

Statistical analyses of the data involved an ANOVA procedure. Dependent variables were F1 and F2. There were five independent factors: Person (P); a subject grouping factor, Sex (S); Trigger (T) (emphatic, /q/, or no trigger); the presence of a Blocker (B), and the Identity of the blocker (I). The blocker identity factor is nested in the blocker presence factor. Trigger and blocker presence are cross-classified. Only two targets were missing, they were given a value which is the average of the other two repetitions of the same word. SAS was used to calculate a three-way repeated, measured ANOVA.

Based on previous works, we expected to find a main effect of trigger, such that emphatics, and possibly /q/, create lower F2's in the target vowels. In addition, if there is no blocking of the uvularization spread, we expected no interaction between trigger and blocker presence with respect F2. However, if high segments do act as blockers, we expected an interaction between trigger and blocker presence, such that the effect of trigger appears only in the absence of a blocker.

2.4 Results

Table 3 summarizes the results of the full ANOVA with subject as a fixed factor. The left part of the table reports results for F1, and the right, results for F2. Most factors show a significant effect in the fixed effects analysis. However, to determine what is common across the speakers, a repeated measures analysis was done by comparing the mean squared variance for each factor with the variance present for that same factor's interaction with the subject factor (P). Calculating F-values in this fashion yielded the results presented in Table 4.

For F1, there are four significant factors, Trigger by Blocker Identity (T*I(B)), Trigger by Blocker Presence (T*B), Trigger (T), and Sex (S). All other effects are insignificant. Thus, the presence of a trigger has an effect on the target vowel, though it is mediated by the presence of particular blocking segments.

The results in this case suggest that the presence of a trigger causes a long distance spreading onto the target vowels, and that some of the high segments block the spreading. Male and female speakers show different average F1's, as would be expected due to differences in vocal tract lengths.

We believe that the Trigger by Blocker Identity effect is the result of an error in the design of the corpus for the reasons that follow. Target vowels varied idiosyncractically in quantity. A subsequent study (de Jong and Zawaydeh, 1999) has found a systematic difference in the F1 of long and short vowels, but no such difference in F2 for this dialect. Since vowel quantity is distributed irregularly in this corpus, most vowels following /q/ and most vowels following /u/ and /i/ blockers, this would account for the interaction effects.

For F2, there are three significant factors, Trigger (T), Blocker Identity (I(B)), and Sex (S). Unlike F1, there is no interaction between the presence of the trigger and a blocking segment, but, there is again an overall difference in the F2's of male and female speakers.

The Trigger and Blocker Identity effects were submitted to a set of post-hoc comparisons with a significance criterion of two standard deviations. All three categories differed significantly from one another. F2's following emphatics had the lowest values, F2 measurements following /q/ had values between those of the emphatics and those of the non-emphatic coronals, while being significantly different than both of them.

Comparisons of the different blocking segments indicate that the blocker effect is due the /w/ having a signficantly lower F2 than any of the other categories, including the /u/ blocker category. Thus, these results indicate a long distance effect of emphasis and of /q/ which is the same in effect, though different in degree. In addition, there is a local effect of having a /w/ immediately preceding the target vowel.

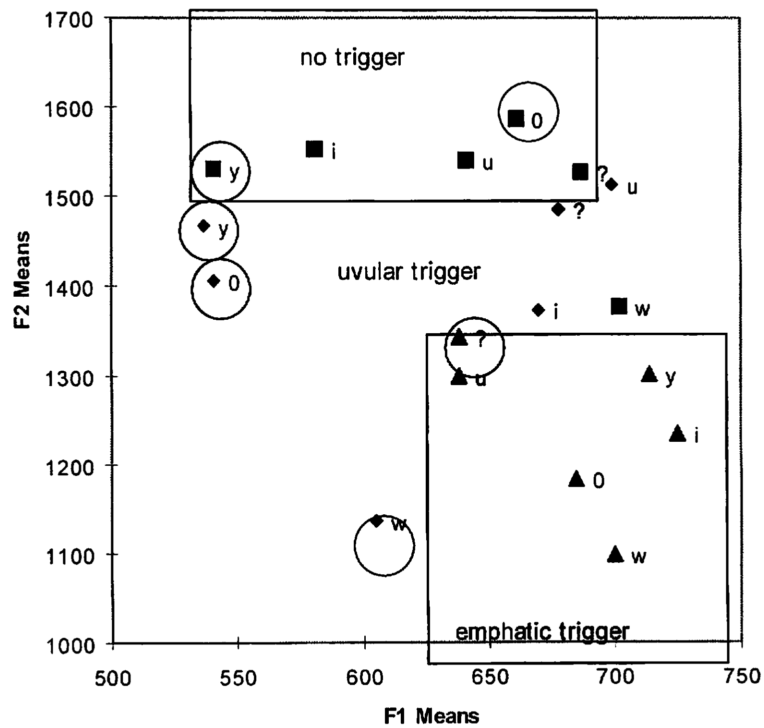
	F1					F2				
Factor	d.f.	SS	Mean Sq.	F	p	d.f.	SS	Mean Sq.	F	p
P*T*I(S*B)	32	618057	19314	5.13	0.0001	32	1469832	45932	4.15	0.0001
S*T*I(B)	8	164623	20577	5.46	0.0001	8	443386	55423	5.01	0.0001
T*I(B)	8	580982	72622	19.27	0.0001	8	364226	45528	4.11	0.0001
P*T*B(S)	8	46830	5853	1.55	0.1404	8	480562	60070	5.43	0.0001
S*T*B	2	13050	6525	1.73	0.1795	2	37998	18999	1.72	0.1823
T*B	2	134527	67263	17.85	0.0001	2	178807	89403	8.07	0.0004
P*T(S)	8	150928	18866	5.01	0.0001	8	111313108	139138	12.57	0.0001
S*T	2	38439	19219	5.1	0.0069	2	845337	422668	38.17	0.0001
T	2	218369	109184	28.97	0.0001	2	4129524	2064762	186.47	0.0001
P*I(S*B)	16	611124	38195	10.14	0.0001	16	877256	54828	4.95	0.0001
S*I(B)	4	56762	14190	3.77	0.0055	4	145521	36380	3.29	0.0122
I(B)	4	188614	47153	12.51	0.0001	4	2387359	596839	53.9	0.0001
P*B(S)	4	22039	5509	1.46	0.2148	4	90512	22628	2.04	0.0894
S*B	1	1920	1920	0.51	0.4760	1	57960	57960	5.23	0.0231
B	1	18918	18918	5.02	0.0261	1	520	520	0.05	0.8286
P(S)	4	1356217	339054	89.97	0.0001	4	334349	83587	7.55	0.0001
S	1	1659802	1659802	440.45	0.0001	1	2327658	2327658	210.21	0.0001

Table 3. KEY: P=Person, S=Sex, T=Trigger, I=Blocker Identity B=Blocker Presence.

	F1						F2					
Factor	d.f.	SS	Mean Sq.	F	p	sign.	d.f.	SS	Mean Sq.	F	p	sign.
P*T*I(S*B)	32	618057	19314	Residual			32	1469832	45932	Residual		
S*T*I(B)	8	164623	20577	1.06	0.41	-	8	443386	55423	1.2	0.326	-
T*I(B)	8	580982	72622	3.76	0.003	+	8	364226	45528	0.99	0.461	-
P*T*B(S)	8	46830	5853	Residual			8	480562	60070	Residual		
S*T*B	2	13050	6525	1.11	0.374	-	2	37998	18999	0.31	0.737	-
T*B	2	134527	67263	11.49	0.004	+	2	178807	89403	1.48	0.282	-
P*T(S)	8	150928	18866	Residual			8	1.1E+08	139138	Residual		
S*T	2	38439	19219	1.01	0.403	-	2	845337	422668	3.03	0.104	-
T	2	218369	109184	5.78	0.027	+	2	4129524	2064762	14.83	0.002	+
P*I(S*B)	16	611124	38195	Residual			16	877256	54828	Residual		
S*I(B)	4	56762	14190	0.37	0.825	-	4	145521	36380	0.66	0.626	-
I(B)	4	188614	47153	1.23	0.335	-	4	2387359	596839	10.88	0	+
P*B(S)	4	22039	5509	Residual			4	90512	22628	Residual		
S*B	1	1920	1920	0.34	0.586	-	1	57960	57960	2.56	0.184	-
B	1	18918	18918	3.43	0.137	-	1	520	520	0.02	0.886	-
P(S)	4	1356217	339054	Residual			4	334349	83587	Residual		
S	1	1659802	1659802	17.92	0.013	+	1	2327658	2327658	27.84	0.006	+

Table 4. KEY: P=Person, S=Sex, T=Trigger, I=Blocker Identity B=Blocker Presence.

These effects can be seen in Figure 1, which plots average F1 against average F2 across all of the speakers. In the figure, shape indicates the long distance effect of uvularization. The identity of the neighboring blocking segment is indicated by labels next to the symbols. Ignoring the targets following /w/, the three-way distinction in F2 between triangles (emphatics at 1100 to 1300 Hz), diamonds (/q/ at 1300 to 1500 Hz) and squares (controls at 1500 to 1700 Hz) is very clear. Emphatics cause the most lowering, and /q/ also causes lowering, though to a lesser degree. All three groups are distinctly different. It is also clear that a /w/ immediately preceding the target lowers the average F2 approximately 200Hz, independent of the uvularization effect. The figure also shows the non-significant difference between the emphatic cases with no blocker, with an F2 of under 1200 Hz, and the other blocking conditions with average F2's ranging from 1200 to 1300 Hz. Examining the F1 dimension shows an overall lower F1 for short vowels, which are indicated with a circle around them. This difference is irregularly distributed across the Trigger and Blocker Identities. Thus, the general conclusion of Experiment 1 is that there is perseveratory uvularization spread which is not categorically affected by blockers, and this uvularization is well-indexed by the F2 of the low vowels.



Means Across All Six Speakers

Figure 1. Qualities of target vowels one syllable after emphatic (triangles), uvular (diamonds), and non-uvularized and non-uvular (squares) consonants. Symbols which are circled are short vowels; others are long.

As an exploratory test, ANOVA's were also run for individual speakers. These revealed significant interactions between the Trigger and Blocker Presence factors in five of the six subjects. Closer examination of this data shows that blocking occurred only when the trigger was a [q]. In no instances did the blocking occur with an emphatic trigger.

3 Experiment 2

Previous studies have suggested that while perseveratory emphasis spreading may be affected by blocking segments, anticipatory spreading does not. Experiment 2 examines a corpus of data like that in Experiment 1, except that the target precedes the trigger. In addition, to make the analysis more manageable, the number of blocking segments was reduced and the /q/ trigger was eliminated.

3.1 Subjects

The six subjects were the same three female and three male Ammani-Jordanian Arabic speakers in Experiment 1.

3.2 Stimuli and Materials

The lexical corpus used in Experiment 2 is detailed in Table 5. Tokens listed in the column labeled 'Emphatic" elicit low vowels preceding a syllable containing emphatic coronals. Tokens listed in the column labeled 'No Emphatic' elicit low vowels preceding a syllable containing no emphatic consonants. Within these conditions, only 3 blockers [w, j, i] were used. Emphatic segments are indicated by subscript dots.

Blocker	No emphatic	Emphatic
none	/dal<u>aa</u>laat/ 'indications'	/sal<u>a</u>t¢¢aat/ 'salads'
y	/x<u>a</u>yaal/ 'shadow'	/x<u>a</u>yyaat¢/ 'tailor'
i	/man<u>aa</u>fid/ 'exits'	/man<u>aa</u>fid¢/ 'ashtrays'
w	/m<u>a</u>waad/ 'subjects'	/m<u>a</u>waad¢ii?/ 'topics'

Table 5. Linguistic Corpus for Experiment 2.

3.3 Procedure and Measurements

Recording and digitizing methods were the same as in the previous experiment. Estimates of F1 and F2 were performed as in experiment 1. Since quantity is not fixed in the target vowels, F1 was not analyzed.

3.4 Results

There are three independent variables in the current design, the presence of an emphatic Trigger, the presence of a high Blocker, and subject. Thus, F2 values were subjected to a 3-way ANOVA. The ANOVA indicated an effect of subject ($F(5,111)=7.758$, $p < 0.05$), Trigger ($F(1,111)=138.327$, $p < 0.05$), an interaction between Blocker and Subject ($F(5,111)=2.650$, $p < 0.05$), and an interaction between Trigger and Subject ($F(5, 111)=6.552$, $p < 0.05$). Since there was no interaction between Trigger and Blocker, we conclude that high segments do not block the anticipatory spreading of uvularization from emphatics.

Figure 2 plots average F1 and F2 for each lexical item. Diamonds denote tokens containing emphatic consonants, and circles indicate non-emphatic conditions. The F2 of low vowels in all emphatic environments are valued below 1300 Hz while all non-emphatic tokens have F2 values above 1300 Hz, regardless of the presence of blocking conditions. We conclude that none of the three high segments /j, i, w/ block leftward emphasis spread.

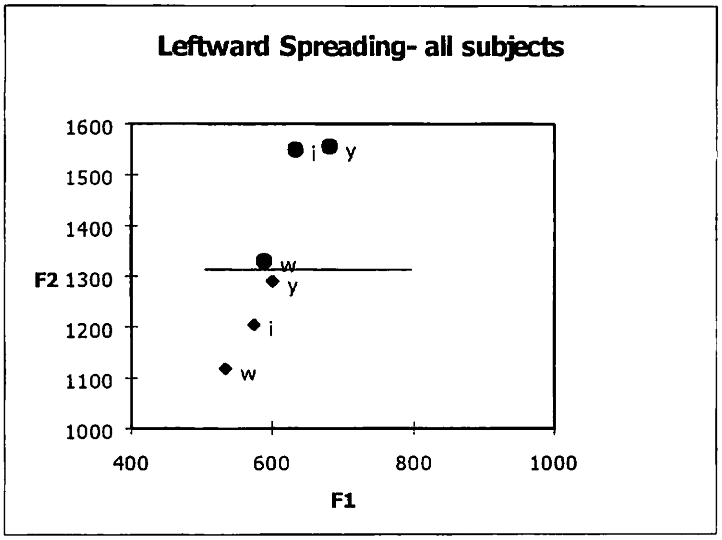


Figure 2. Vowel qualities for low vowels preceding triggering (diamonds) and non-triggering (circles) consonants with various blocking segments intervening.

4 Experiment 3

In the first two experiments, neither the anticipatory nor the perseveratory spreading of uvularization is blocked by the presence of high segments. In this section we examine effects of distance from Trigger to Target.

4.1 Subjects

The subjects for this experiment are the same subjects used in the previous two experiments.

4.2 Stimuli and Materials

Table 6 presents the corpus for Experiment 3. Here, multiple target vowels in some of the words were used to examine the distance effects on spreading. These words were presented three times to the subjects in a list that also contained distracter words.

Location of Vowel	Perseveratory Spreading	Anticipatory Spreading
2 consonants away	/ʔad¢alaatak/ 'your muscles'	/tasallat¢/ 'he overruled'
1 consonant away	/ʔad¢alaat/ 'muscles'	/ salat¢aat/ 'salads'
0 consonants away	/ salat¢aat/ 'salads'	/ʔad¢alaatak/ 'your muscles'

Table 6. Lexical items used for Experiment 3. Emphatic segments are indicated by subscript dots

4.3 Procedures and Measurements

The recording and spectrographic analysis procedures are identical to those that were used in the previous two experiments.

4.4 Results

The F2 measurements were subjected to a 3-factor ANOVA with distance (from the emphatic), direction of spreading, and subject as factors. The distance factor had a significant main effect on F2 ($F(2,64) = 42.675$, $p < 0.0001$), but the direction factor did not ($F(1, 64)=1.732$; $p = 0.1928$). There was also a significant effect of the interaction between direction and distance ($F(2,64) = 69.288$; $p < 0.0001$). Finally, the subject factor was significant ($F(5,64) = 20.847$; $p < 0.0001$), and it interacted with direction, distance, and the direction by distance interaction. However, since we are not interested in individual idiosyncratic subject effect, we will not discuss subject factor results.

Tukey post-hoc tests were performed to determine the cause of the distance effect and its interaction with direction. For anticipatory spreading, we found no significant difference between any of the three distance conditions, that is, whether the consonant is 0, 1, or 2 consonants away. For perseveratory spreading, there is a significant difference between vowels which are 2 consonants away and those which are 0 or 1 consonant away.

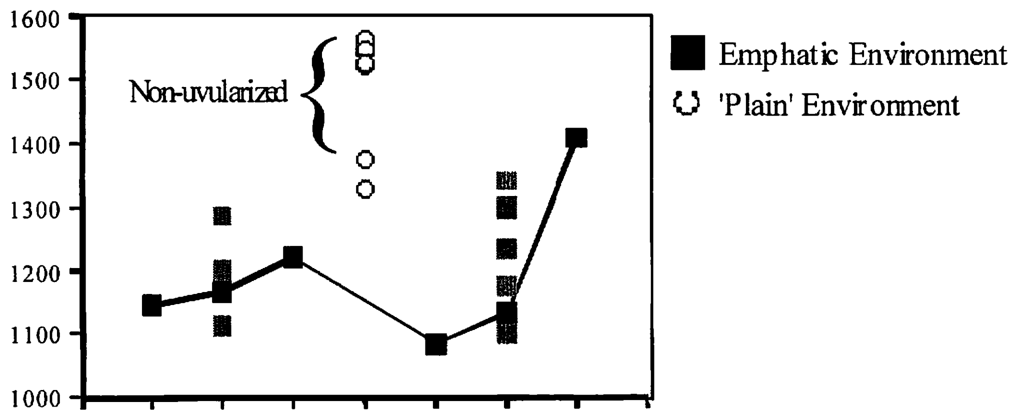


Figure 3. Distance from Target (Number of Vowels). F2's for vowels at various distances from an emphatic trigger. Squares indicate vowels following triggers, and circles indicate vowels preceding triggers.

The pattern of F2's is plotted in Figure 3, where the horizontal dimension indicates location of the target vowel with respect to the trigger. Items to the left precede the trigger, and items to the left follow the trigger. Grey diamonds indicate the results from Experiments 1 and 2, and give an idea of the range of F2's for vowels which are two vowels after or before the trigger. The circles indicate F2's for words without an emphatic. Three general effects are readily discernable. First, the most uvularized vowels are those immediately following the emphatic consonant. Second, as the consonant becomes more distant following the vowel, the amount of uvularization weakens considerably, especially three vowels after the target. This sort of distance-sensitivity in perseveratory spreading was also noted by El-Dalee (1984) for Egyptian Arabic. Note that at no time do the vowels actually have the quality found for the non-emphatic controls in Experiment 1, which had average F2's of about 1700 Hz. The average F2 values here seem to be similar to those found for perseveratory uvularization from /q/ in the first experiment. Third, anticipatory spreading is not sensitive to distance, and is roughly the same as perseveratory spreading found in the syllable following the syllable containing the emphatic consonant.

5 Discussion

This study finds acoustic evidence that uvularization in Ammani Arabic is a non-local phenomenon, detectable at least three syllables away from an emphatic trigger. Differences in the F2's of uvularized and non-uvularized low vowels are large, generally around 500 Hz. However, there are many more differences found here than could be captured by a simple binary representation of the presence of uvularization. We find a statistical difference between uvularization associated with /q/ and that associated with an emphatic. We find a statistical difference between vowels further away from the trigger than those closer to it. We also find a difference between vowels before the trigger and those after the trigger. We assume that these sorts of differences are either simply not indicated in impressionistic investigations of the uvularization phenomenon, all of the different gradations of uvularization counting simply as uvularized, or that the items which are roughly half-way between the vowels next to emphatics and those in control words might variably be labeled as either uvularized or as non-uvularized. Hence, some studies note an uvular effect associated with the /q/, and some do not. Some studies also note a block in the perseveratory spreading, and some do not.

When considering the question of whether uvularization spreading should be encoded in the phonological grammar, or whether it should be considered a non-phonological aspect of the phonetics, we find points to be made for both positions. Regarding the position that uvularization is not phonological in the sense discussed in Keating (1996), we conclude that anticipatory spreading is phonological because it is categorically present. That is, regardless of position and the imposition of various antagonistic segments between the trigger and the targets, the quality of the vowel is consistently that of the back allophone of the low vowel. The perseveratory spreading, however, would appear to be phonetic because it is subject to gradient effects. Specifically, there is a general fading of the degree of uvularization as vowels get further from the trigger. Also, many of the subjects showed some weak effects of the presence of a blocker.

This sort of conclusion, however, is problematic. First of all, it is clear that the uvularization contrast in Arabic is peculiarly expressed as a non-localized contrast, being spread to various locations in the word. This fact, however, is obscured in an analysis which splits one part of the explanation of uvularization distribution into a phonological grammar, and another part into a completely separate and autonomous phonetic module. A unified explanation of the spreading phenomenon is preferable to one with two separate explanations for the same effects in different locations in the word. A second potential problem with this approach is that the uvularization is most strongly expressed in persevaratory uvularization. F2's are systematically the lowest in the vowel following an emphatic. It seems counterintuitive to claim that phonologically specified uvularized vowels systematically show less uvularization than ones which are not phonologically specified as uvularized and to observe that they share some of the uvularization due to phonetic inertia or secondary phonetic planning effects.

Younes (1982) suggests a different conclusion in the study in which he employed a prosodic blocking task to probe speakers' sensitivity to the allophonic variants. He asked two Palestinian Arabs to pronounce, one syllable at a time, words containing an emphatic consonant, with pauses inserted between syllables. He found that these speakers tended to de-emphasize syllables where they insert pauses. He found that vowels immediately following an emphatic were uvularized, regardless of an intervening word or morpheme boundary, as were preceding vowels. Vowels appearing further away from the emphatic, however, varied as to whether they were uvularized or not. That is, speakers often did not abstract the allophonic variant from the lexical form when there was a major prosodic break in the word. This was true for both perseveratory and anticipatory spreading, suggesting no evidence that anticipatory spreading was encoded in the phonological form while perserveratory spreading was not.

Still, it would be preferable to find a single, unified account of uvularization distribution and strength. This account should address the point that the difference between perseveratory and anticipatory spreading may be due to a functional difference between anticipation and perseverance. If one considers that initial locations are advantageous for lexical recognition, as suggested by many traditional models of lexical access, pre-articulating the uvularization contrast would be particularly useful. This may explain the consistency of the anticipatory effects.

Frisch (2000) provides some evidence for temporal assymmetry in Arabic. He shows that the temporal order of the segments in a word influence the phonology. He studied the OCP place constraint in Arabic in which homorganic consonants are disfavored in the root. This constraint applies more frequently to the first two consonants (C1C2) in a triliteral root than to the second two consonants (C2C3) or to non-adjacent pairs (C1C3). Since lexical access happens temporally, rather than in just one step, the difference between the constraint on C1C2 and that on C2C3 is 'not specific to the OCP in Arabic, but is a general cognitive phenomonon affecting the perceived similarity of initial consonants that is caused by the process of lexical access and phonological encoding' (p.12). Frisch also presents work on English illustrating similar increased attention given to word initial segments.

Frisch's results and conclusions parallel the results of our current experiments on uvularization spread in Arabic. One goal operative in speakers' productions is to maximize the contrast between an emphatic and a nonemphatic consonant. If a word contains an emphatic, the speaker maximizes the uvularization contrast (by dropping F2) until the emphatic is articulated. Thus, if there is an emphatic at the beginning of the word, then the expression of contrast will be word initial. In comparison, if there is an emphatic word finally, the contrast of uvularization will be maximized by spreading it throughout the word, until the emphatic is produced. Word onsets have a special status because there is nothing that precedes them, making them stronger than word final emphatics. Word final emphatics compensate by expressing the contrast more strongly throughout the whole word.

The specification of uvularization must also address the aspect of localization. In addition to the existence of the emphatic consonant, the actual location of the emphatic is specified. In the uvularization patterns found in this study, this location is evident by increased uvularization localized on the vowel following the emphatic consonant. This localization seems to match the tendency for languages to localize vocalic specifications of consonants on their release into the following vowel.

6 Conclusions

Our experiments examining uvularization spread in the dialect of Ammani-Jordanian Arabic indicate that the [q] spreads uvularization, like emphatic segments, although its effect is weaker, and, so, has generally not been noted in previous works on the subject. We also find that uvularization does spread, not only to the adjacent segment, but to a location at least three vowels removed from the triggering segments. This spreading is not blocked by high segments, though there is some subject dependent evidence for a weakening effect of high segments on perseveratory spreading.

This study also finds that perseveratory spreading is temporally gradient, weakening as the target is further from the trigger, but finds no evidence for temporal weakening of anticipatory spreading. However, since both kinds of spreading share attributes, it is appropriate to look for a unified explanation for the localization of the uvularized contrast. Such an explanation would include directional differences and localization of the contrast, and would bridge the gap between a phonological specification of contrast and the gradient realization of the contrast in lexical items.

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