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AN ACOUSTIC ANALYSIS OF UVULARIZATION SPREAD IN AMMANI-JORDANIAN ARABIC[*]

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1. Introduction to the Problem

Uvularization[1] as a secondary articulation is defined as the retraction of the back of the tongue accompanying primary articulation at another point in the vocal tract (al-Ani 1970; Ghazeli 1977; Herzallah 1990; Younes 1993; Davis 1993, 1995). In Arabic, the only segments that have this secondary articulation are the phonemes /ṭ, ḍ, ṣ, ẓ/. Another class of sounds that are articulated via the retraction of the tongue root are the uvulars /χ, ʁ, q/. In this case, the back of the tongue makes contact with the uvula. Thus, both uvularized and uvular sounds have one point of articulation in common: the uvula. In the uvularized sounds, it is a secondary articulation, while in the uvular sounds it is a primary one (see the X-ray pictures in Ghazeli 1977 for details).

According to Ghazeli 1977, Younes 1982, Herzallah 1990 and others, secondary uvularization is characterized by a drop of the second formant in the vowels and sonorants in general. Also, there is a slight rise in the first formant in the segments that are affected by uvularization spread. Thus, uvularized consonants are different from plain consonants in that they have a more compact spectrum. In comparison to uvularization, uvular spreading also causes a drop of the second formant in the adjacent vowels and sonorants. However, this drop is weaker than the one caused by the uvularized segments. Futhermore, it has been found that the dorsum of the tongue approximates the upper part of the pharynx in the articulation of uvularized and uvular sounds.

Hence, because of the involvement of two articulators, the dorsum and the pharynx, the features [dorsal] and [pharyngeal] have been selected by Herzallah 1990 to describe the double articulation of uvularization. Other features that have been used to describe uvularization were [+low, +back], by Chomsky & Halle 1968, [+Constricted Pharynx] by McCarthy 1986, and a new representation of these uvularized coronals is proposed by Davis 1993, 1995 within the framework of Feature Geometry where uvularization is represented by the feature Retracted Tongue Root (or [RTR][2]) under the Pharyngeal node. This feature has been chosen because it follows the findings of the literature on the acoustics of uvularized segments. Since the retraction of the tongue root is one of the basic components for the articulation of uvularized and uvular segments, the feature [RTR], was found to be appropriate. Thus, in Davis's account the uvulars and uvularized segments are the only segments that have the RTR feature. In comparison, the other gutturals (the pharyngeals and laryngeals) do not.[3]

In Arabic, the uvularization feature of a phoneme can spread in both directions; rightward and leftward. In the various dialects, the leftward spread is usually unblocked, while the rightward spread can be blocked by some opaque segment. Interestingly, the opaque segments are almost always the high (and/ or front) phonemes /i, j, š, ž, u, w/. The following table presents the opaque segments in some Arabic dialects:

Table 1: Opaque segments in some Arabic dialects

Dialects	Opaque segments	Study done by
Moroccan	i, j, š, ž	Heath 1987
Northern Palestinian	i, j, š, ž, u, w	Davis 1995, Herzallah 1990, Younes 1993
Southern Palestinian	i, j, š, ž	Davis 1995
Libyan	i, e	Ghazeli 1977

I believe the reason high segments could be opaque is that the time needed to produce a high segment (as an /i/ for example) is not important by itself, rather what might be happening is that when a high segment is uttered after pronouncing a uvularized segment, the tongue root does not go back to the retracted position that it occupied during the articulation of the uvularized segment. Thus, when the word /ṭæfdiilææt/ 'preferences' is articulated, if the [i] is an opaque segment, instead of pronouncing the whole word in a uvularized fashion, when the tongue body is raised for the articulation of [i] in that particular dialect, it would not go back to the retracted tongue position, but rather to the neutral nonretracted position. This explanation agrees with Davis's 1995 that the retraction of the tongue root required for the articulation of uvularized segments is 'antagonistic' to the [front] (or [-back]) and [high] features of a segment like [i]. This might more plausibly explain why high segments are opaque.

In this paper, I study the manner of uvularization spread in Jordanian Arabic from the uvularized segments /ṭ, ḍ, ṣ ẓ/ and the spreading from the uvular /q/. The purpose of the study is to examine the extent of spread in order to see if there are any opaque segments that block it and to see whether the spread is triggered by both the uvularized and uvular segments. Furthermore, I examine the acoustic properties of other uvular consonants, /χ/ and /ʁ/, in Ammani-Jordanian Arabic. I distinguish the underlying phonemes /χ/ and /ʁ/ from the uvular /q/ because impressionistically (and as I demonstrate in section 2.1, acoustically) the former do not influence the neighbouring vowels as /q/ does. They do not seem to spread uvularization as the uvular stop does; I suspect this is because they are phonetically velar, not uvular.

The outline of the remainder of this paper is as follows. In section 2, I present an acoustical analysis of uvularization spread from the uvularized segments. Specifically, I investigate the effect of the high segment in blocking uvularization spread. In section 3, I deal with two issues. In 3.1, I reveal the velar nature of the phonemes /χ/ and /ʁ/ in Ammani-Jordanian. In 3.2, I present an investigation of the nature of uvularization spread from the uvular /q/ and the effect of the high segments in blocking uvularization spread from /q/. Finally, the conclusion is presented in section 4.

2. Secondary Uvularized Segments Triggering Uvularization Spread

Impressionistically, the leftward and rightward spread of secondary uvularization is unblocked in Ammani-Jordanian. Moreover, uvularization spread is not limited to stems only. It can also spread into prefixes and suffixes. Because of the lack of any systematic studies done about uvularization spread in Jordanian Arabic, I was motivated to try to verify the spread of uvularization with quantitave measures.

2.1 Method

2.2 Subject

The subject of this study is the author, a twenty-five year old female graduate student at Indiana University who speaks the urban dialect of Amman, the capital of Jordan. The second languages that I speak are English and French.

2.3 Stimuli and Materials

The data were designed to test the spread of uvularization from the uvularized consonants rightward to the low vowel [æ] (or its long version [ææ]). In order to see if any of the potentially blocking segments do block uvularization spread, the data have the following four conditioning environments (C stands for a plain consonant, C̲ for a uvularized consonant, V for a vowel, and B for a Blocker; a potentially blocking segment, the low front vowel is indicated as [æ] and the uvularized version of it is indicated as [ɑ]:

1. CVBV: The first consonant is plain, the second one is a blocker: one of the six potentially blocking segments [i, u, š, ž, w, j], as in /tæwæbeʕ/ 'following'.

2. C̲VBV: The first consonant is uvularized, the second one is a potentially blocking segment, as in /ṭæwæ/ 'he folded'.

3. C̲VC̲: The two consonants are uvularized, as in /bæṭæṭæ/ 'potatoes'.

4. C̲VCV: The first consonant is uvularized, the second one is plain; i.e., it is not one of the potentially blocking segments, as in /ṭælæl/ (a name).

Note that if the blocker is a vowel, as in the case of [ii] or [uu], then there would be a plain consonant following the blocker, and the low vowel follows that plain consonant, as in /tæfḍiilææt/.

The reason the low vowel was chosen for analysis rather than /i/ or /u/ is that the low front vowel has relatively mid F1, F2, and F3. In comparison, [i] has a high F2 and F3, while [u] lowers all the formants. Since the goal is to study the effect of uvularization on F2, it is best to choose a vowel whose F2 is neither high nor low. Table 2 below includes all the words that were used in this experiment to test the above-mentioned four conditioning environments:

Table 2: Tokens used in this experiment

Condition 1: CVBV	Condition 2: C̲VBV	Condition 3: C̲VC̲V	Condition 4: C̲VCV
/tæwæbeʕ/ 'following'	/ṭæwæ/ 'he folded'	/bæṭæṭæ/ 'potatos'	
/dæjjænæthæ/ 'she lent her'	/ḍæjjæʕæthæ/ 'she lost it'	/ʔuṭæṭ/ 'kittens'	/ḍællæk/'stay'
/dæššæt/. 'she ground'	/ṭæššæt/ 'she ran away		
/tææžæk/ your crown	/ṭæžžæt/ 'she bounced a ball		
/fuulæk/ 'your beans	/ṭuulæk/ 'your height		
/bædiilææt/ 'alternatives'	/tæfḍiilææt/ 'preferences'		

The words in condition 1 and condition 2 were chosen so that the difference between them would only be whether the word starts with a uvularized or a plain phoneme. Thus, each of the words that contained a potential blocker had a corresponding word that also had the same blocker, but no uvularized segment. For the sake of consistency of data, we had to use in one case an uncommon slang word, which is /ṭæššæt/, and in another case a word that is archaic, /dæššæt/. However, both of them are phonetically possible Arabic words.

Furthermore, it is worth mentioning that the words that were selected were ones that do not have a bilabial or a nasal consonant in them (especially before the low vowel) because these sounds are known to have the effect of lowering the vowel formants.

The sixteen utterances that were described above were presented randomly five times in a list of 80 tokens. 50 of those were words that had uvularized segments and 30 of them were words that contained no uvularized segments. Moreover, 25 distractors were also included and presented randomly. These extra sets of words were used to reduce the probability that the speaker would be primed to spreading the uvularization pronunciation to all the words from their beginning to their end. Thus, in sum, the total number of the tokens that were recorded was 105.

2.4 Procedure

The list of the words from 1 to 105 were read, first reading the number of the probe and then the probe. The probes were not given in sentences or phrases to avoid having any other conditions that might affect the spread of uvularization, such as the rate of speech, stress placement in the sentence, or adjacent words.

The speaker spoke into a microphone and the stimuli were recorded on a reel of tape with the two-track reel-to-reel in the phonetics recording room in the Indiana University Phonetics Laboratory. The data were digitized through a Macintosh using Soundscope. Then Soundscope was again used to produce individual spectrograms of each utterance so that the relevant vowels might be picked out and analyzed. The data were analyzed by using the built-in analyzer that provides readings of all the desired formants, or when the program failed to give a formant in the region expected (which rarely happened), a visual examination of the sprectogram was done, though this technique was much less accurate. With regard to the first technique, the formant measuring cursor was placed on the middle of the vowel, which is also the steady state of the vowel. There were 13 LPC coefficients and the LPC frame length was 20 ms. If the measurements that Soundscope calculated did not correspond to values expected by observing the spectrogram, i.e., if Soundscope gave only the measurements of the first formant and its ghost formants instead of giving the second formant also, a visual examination of the spectogram was done, and we tried to get an approximation of what the first and second formants were. This technique was used about three times.

2.5 Results

In this section the results of the Fl and the F2 mean values will be discussed. Figure 1 demonstrates the mean values of the first and second formants of the low vowel that follows the potential blocking segment in the five repetitions of each one of the tokens. The six tokens: /tæw**æ**beʕ, dæjj**æ**næthæ, bædiil**ææ**t, fuul**æ**k, dæšš**æ**t, tææž**æ**k/ are condition 1 tokens: CVBV. The six tokens: /ṭæw**æ**, ḍæjjæʕæthæ, tæfḍiil**ææ**t, ṭuul**æ**k, ṭæšš**æ**t, ṭæžž**æ**t/ are condition 2 tokens: C̲VBV. The words /bæṭ**æ**ṭæ/ and /ʔuṭ**æ**ṭ/ are condition 3 tokens: C̲VC̲V, and finally the words /ṭæl**æ**l/ and /ḍæll**æ**k/ are condition 4 tokens: C̲VCV. (The vowel in bold in the transcription is the vowel whose formant frequencies are measured in Figure 1. The meaning of these words can be found in Table 2).

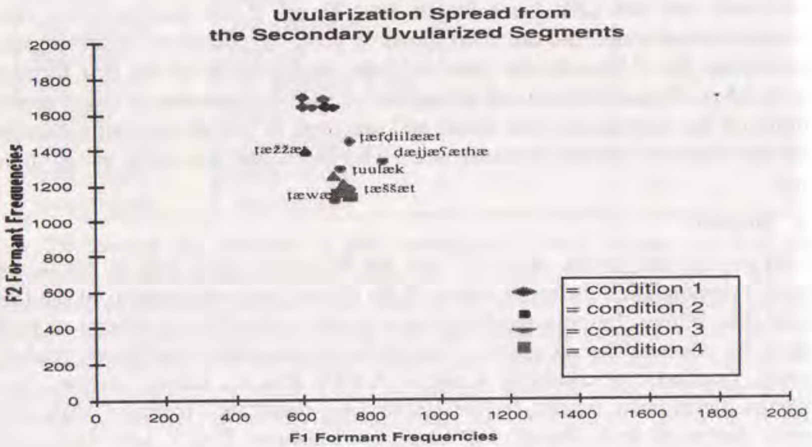
2.6 F1 Results

Previous research found that uvularization spread from the uvularized segments causes a slight rise in the Fl value. The results of this study support this idea. Looking at Figure 1, the tokens in condition 2, 3, and 4 that are in the uvularized environment are almost all slightly higher than the tokens in the plain environment in condition 1 (except for /ṭæžžæt/ whose second vowel has a low Fl frequency). Thus, since the Fl value of the low vowel in the uvularized environment is higher than the Fl value in the plain environment, this could be the first evidence that the high segments do not block uvularization spread in this dialect. Uvularization is spreading from a uvularized segment to the low vowels that are preceded by high segments.

2.7 F2 Results

Looking at Figure 1, if the high segments are blocking uvularization spread, then we expect the F2 of the tokens in condition 2 to be as high as the F2 tokens in condition 1. However, if one examines the means of the vowels in the uvularized environment in Figure 1 (i.e., condition 2), one will notice that all the low vowels in the words that have a uvularized phoneme have low F2 values. Moreover, even the highest F2 mean, which is 1442 Hz (for /ṭæfḍiil**æ**æt/), is not as high as the F2 values in the plain environment. Therefore, the general conclusion is that the uvularized segments do affect the following low vowels by lowering the F2 values, even if there is an intervening high segment.

Figure 1: Fl and F2 mean values of the low vowels in the uvularized environment



If one examines the mean values of the F2 of the low vowels following the potentially blocking segments in condition 1, one will see that when there is no uvularization spread, the F2 values of a low vowel is in the range of 1630 and 1694 Hz. Thus, in general, the F2 value of a low vowel in a plain environment where there is no secondary uvularized segment in the word is usually not lower than 1600 Hz.

The question may be raised: how different are the F2 values of the low vowels following the different blockers in the uvularized environment? Looking at Figure 1, one notices that the blocking segment that most affects the F2 of the low vowel in the uvularized environment is the vowel [i], because the vowel that follows it has the highest F2 mean values. Does this mean that [i] is a blocker? Moreover, there is a lot of variance in the five repetitions of the probe /ṭæf-ḍiilææt/. The F2 values of the five repetitions of /ṭæfḍiilææt/ were 1627, 1576, 1434, 1302, and 1271 Hz. Why would there be such a big difference among the five repetitions in the same word? The way to determine whether the [i] is a blocking segment or not is to determine whether there is a significant difference among the F2 values of the low vowel in the four conditioning environments. Table 3 lists the F2 mean values of the low vowel following an [i] in the four conditioning environments.

Table 3.

Condition 1	CVBV	/bædiilææt/ 'alternatives'	1681 Hz
Condition 2	CVBV	/ṭæfḍiilææt/ 'preferences'	1442 Hz
Condition 3	CVCV	/ḍællæk/ 'stay' /ṭælæl/ 'a name'	1244.6 Hz 1206.2 Hz
Condition 4	CVCV	/bæṭæṭæ/'potatoes' /ʔuṭæṭ/ 'kittens'	1146.2 Hz 1148.4 Hz

A Tukey t-test was done at the significance level of .05. The results of this t-test are given below in table (4):

Table 4: Tukey compromise

Effect: Condition
Dependent: F2
Significance level: .05

Condition		Difference	Critical Difference	
3	4	60.000	142.224	
	2	295.800	155.337	S
	1	534.800	163.406	S
4	2	235.800	142.224	S
	1	474.800	155.337	S
2	1	239.000	142.224	S

In this table, the first and second columns show the conditions and their interaction with each other. The third column shows the difference between them, and the fourth column shows the critical difference. The 'S' in the fifth column indicates whether the difference is significant or not. The difference between conditon 1 and condition 2 is significantly different. Thus, we come to the conclusion that the [i] does not block uvularization spread.

As for the reason why vowels after the [i] would have higher F2 values, it might be because of a coarticulation effect. [i] raises F2 in the same way that the /u/ lowers it (along with the other formants). This is why there is a difference between the mean value of the low vowels following the [i] and the [u]. The former was 1442 Hz, while the latter was 1289.4 Hz.

With regard to the question why there is a large variance between the five repetitions in condition 2, as mentioned above, this could be because the spread of uvularization in this case is optional. Thus, after raising and fronting the tongue body, one could either keep the tongue fronted, and thus produce a fronted low vowel, or since there is a uvularized phoneme in the environment, one could move the tongue from the fronted position to the back position, thus one would say [ṭɑfḍiilææt] instead of [ṭɑfḍi̱i̱lɑɑṭ]. Both cases are accepted and do not make any difference semantically.

Another possibility that could explain why the F2 values of this low vowel following the [i] is higher than other vowels is that the low vowel is farther away from the uvularized consonant. In this case, we are referring to the fact that there is a consonant between the low vowel and the potentially blocking segment in /tæfḍiilææt/. In comparison, in other words where the high segment is a consonant, there is no other consonant (cf. /ṭæwæ/). However, I believe that this could not be the reason because in a minimal pair such as /ṭiinæk/ 'your mud' and /tiinæk/ 'figs', where the first word starts with an uvularized phoneme and the second with a plain alveolar stop, one can hear a clear difference between the two low vowels. The first is definitely a back vowel while the second is front. Thus, we know that the [ii] does not block uvularization spread. Hence, it seems that the spread into the suffix *-ææt* is optional.

The next question is whether uvularization spread to all suffixes is optional. The answer is no. We have evidence in the data that this is not the case. The words that have suffixes and had also uvularization spread are the words /ṭæž-žæt/, /ṭæššæt/, and /ṭuulæk/. The *-æt* suffix is the singular feminine suffix, while *-æk* is the second person masculine singular suffix. In the three words, uvularization spreads from the uvularized phoneme without the high segment blocking uvularization. A Tukey t-test was done for F2 values of the low vowels of these words. At the significance level of .05, we found that there is no significant difference between the F2 values in condition 4 and condition 2, i.e., there is no significant difference between the F2 values of the low vowel following a blocker and the F2 values of the vowel in the uvularized environment following a plain consonant. This was found when the blocker was [u] or [š].

2.8 Discussion and Conclusion

The high segments [w, j, i, u, š, ž] do not block uvularization spread in the dialect of Jordanian Arabic considered in this study. When there is a uvularized phoneme in the word, the low vowels have a slightly higher F1 and a lower F2 than in plain environments where there is no emphatic. Thus, low vowels in the uvularized environment become pronounced further back. Moreover, there are indications that the spread into the plural suffix *-ææt* might be optional. In comparison, uvularization does spread to other suffixes such as the feminine singular suffix *-æt* and the 2nd person masculine singular suffix *-æk*.

The results of this study make Jordanian Arabic similar to Tunisian and Cairene Arabic (Younes 1993; Schulte 1985). Schulte found that there is bidirectional spreading of uvularization in Cairene Arabic. This spreading is obligatory into prefixes, while in suffixes it is sometimes optional and other times obligatory. It is obligatory when the stem ends in a uvularized phoneme, as in the word /biḍ-ææt/ 'eggs'. (This also holds for Ammani-Jordanian Arabic.) In comparison, spreading is optional in words whose stem does not end in a uvularized phoneme. An example is the word /ṣoot-æk/ 'your voice'. This word could be pronounced with either a uvularized suffix or a plain suffix. In our study, we found the same

thing happening in the word /tæfḍiilææt/ 'preferences'. Since the stem did not end in the uvularized phoneme, uvularization spread was optional into the suffix *-ææt*. If the /l/ were a uvularized phoneme, the low vowel would obligatorily be uvularized.

The phonological implications of these results are that the uvularized consonants could be analyzed as having an underlying [+RTR] feature that spreads bidirectionally to both edges of the word. What forces us to say that the [RTR] is linked to the coronal consonant rather than being a floating feature independent of the phoneme is that the spreading is obligatory in the suffix in a word such as /biḍææt/ 'eggs', where the underlying uvularized phoneme is next to the suffix, but optional in /ṣootæk/ 'your voice' (and in /tæfḍiilææt/ 'preferences') when it is not adjacent to the suffix. Thus, /bidææt/ surfaces as [biḍɑɑṭ], while /tæfḍiilææt/ surfaces as either [ṭɑfḍi̱i̱lɑɑṭ] or [ṭɑfḍi̱i̱lææt]. In the latter case, in [ṭɑfḍi̱i̱lææt], the RTR feature would not be linked to the last syllable. As for the reason why the high segments do not block, one could suggest that these segments are underspecified for that antagonistic feature that blocks the spread in other dialects. Thus, this [high] feature would be filled in later by a context-free redundancy rule such as: [ ] → [+high]. However, more evidence for the underspecification of high segments needs to be found in future research.

3. Uvular Triggering Uvularization Spread

In Arabic dialects, historically, there are three uvular consonants: the voiceless uvular stop [q], the voiceless fricative [χ] and the voiced fricative [ʁ]. However, in some dialects like Cairene Arabic and Northern Palestinian Arabic, the last two are velar [x] and [ɣ] rather than uvular (Herzallah 1990). Furthermore, the Arabic dialects differ in the way the uvular stop is produced. In some dialects, /q/ is produced as a voiced velar stop [g] (especially in Bedouin dialects), in others as a glottal stop, and in some as a voiced uvular trill [ʀ] (Ghazeli, 1977).

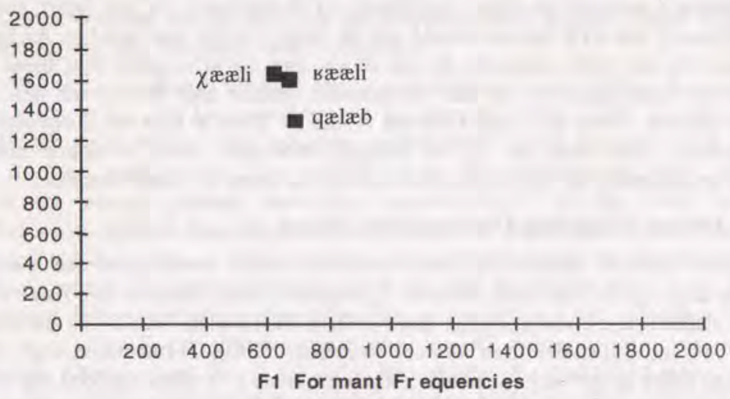
Since the constriction of uvulars resembles the constriction of uvularized segments, we would predict the uvulars to be inherently uvularized. Thus, their plain counterparts could be considered as velars. However, unlike the uvularized phonemes, these plain counterparts have a different place of articulation. The plain counterparts of the secondary uvularized segments /ṭ, ḍ, ṣ, ẓ/ are the alveolars /t, d, s, z/. Thus, the uvular sounds do not really contrast with others that have the same place of articulation, as the secondary uvularized sounds do.

Hence, the issue that needs to be investigated is whether the effect that uvulars have on the following vowels is similar to the effect that the uvularized segments have on the following vowels. Specifically, do uvulars phonologically spread uvularization to the rest of the word as uvularized segments do, or do they just have a low-level phonetic coarticulation effect on the neighboring sounds? In 3.1, I try to identify the nature of the consonants /χ/ and /ʁ/ in Ammani Jordanian Arabic. In section 3.2, I deal with the issue of uvularization spread from the uvular /q/.

3.1 The Nature of /χ/ and /ʁ/

Impressionistically, low vowels that occur after /ʁ/ and /χ/ are not like the low vowels after /q/. I believe that the low vowels in the former case are front, while in the latter, they are back. Consequently, in Ammani Arabic, as in Palestinian Arabic, the /χ/ and /ʁ/ are not realized as uvulars. To verify what is claimed above, the Fl and F2 values of the the low vowels of five repetitions of the words /χææli/ 'my uncle' and /ʁææli/ 'expensive' were measured. The same recording, digitization, and analysis of the formants that was used in the previous experiment were used here. The results are illustrated in Figure 2:

Figure 2: Fl and F2 mean values of the low vowels following [χ], [ʁ], and [q]



As one can see in Figure 2, the F2 of the [χ] and the [ʁ] are very high in comparison with the /q/. The mean of the F2 of the low vowel of /ʁææli/ was 1629.8 Hz and the mean of the F2 of the low vowel in /χææli/ was 1599.2 Hz. In comparison, the F2 mean of the low vowel following the /q/ in /qæʕʕæ/ and /qælæb/ was 1322 Hz. This suggests that the /χ/ and /ʁ/ are not uvular because of the high F2 of the low vowels that are following them. If they were uvular, we would have expected the F2 values to be lower by about 250 Hz (or we would expect a rising transition into the vowel). Thus, the conclusion is that the Arabic fricatives /χ/ and /ʁ/ are not uvular in the dialect of Jordanian Arabic spoken in Amman, but rather they are most probably velar. More research would be needed to confirm this point.

3.2 Uvularization Spread from the Uvular /q/

The voiceless uvular stop [q] is articulated by pressing the superior-posterior back of the tongue against the uvula (Ghazeli 1977). As we saw in the introduction, Davis 1993, 1995 classifies uvularized segments and uvulars as sounds that have the feature [Retracted Tongue Root]. In the uvularized segments, this is a secondary feature, while the primary feature is coronal. In the uvular, the RTR is a primary feature. As we mentioned, the uvularized segments and uvulars are the

only consonants that have this feature. In comparison, pharyngeals and laryngeals lack this feature.

In studies on Arabic, uvulars in different dialects are reported to have different effects on the adjacent vowels. Broselow 1976 argues that the uvularized segments and /q/ have the same effect on neighboring vowels. On the other hand, Sayyed 1981 points out that in Moroccan Arabic, the /q/ would never have the same effect on the neighboring consonant that uvularized segments do. The /q/ can affect only adjacent vowels, it does not spread uvularization to the whole word.

If uvularization spreads throughout the whole word, what would happen when there is a high segment in the word? Do high segments block uvularization spread from the uvular or does uvularization from a uvular go beyond the high segment? Below I will discuss the experiment conducted to answer this question.

3.3 Stimuli and Materials

The data were designed to test uvularization spread from the uvular consonant to the low vowel /æ/ or its long version /ææ/. Three conditioning environments were selected. These were:

1. qVBV The word begins with a uvular /q/ which is followed by a vowel (V), a potential blocking high segment (B) and another vowel (V). The high segments that were used were: /w, y, i, uu, ʕ/, as in /qæwwæ/.
2. qVq The word has two uvulars and a low vowel in between, as in /qæqæ/.
3. qVCV The word starts with a uvular. The uvular is followed by a low vowel that in turn is followed by a consonant and a low vowel, as in /qælæb/.

In the first condition, we are interested in the second vowel. The goal is to see if the second vowel preceded by a high segment is articulated as a front or a back vowel. If it is articulated as a front vowel, the high segment should block the spread. If it is articulated as a back vowel, the high segment should not block spread and so uvularization should spread.

In the second condition, we measure the formants of the vowel that is in the environment between two uvulars. Finally, in the third condition, we measure both the first and the second vowels. Table 5 includes all the words that were used to test the three conditions mentioned above :

The seven words above were repeated five times each. These thirty-five words were presented randomly with other words that are not part of the stimuli. The number of the other words was 28. Thus, the total number of words recorded was 63.

Table 5: Tokens used for testing uvularization spread from /q/

Condition 1 qVBV	Condition 2 qVqV	Condition 3 qVcV
/qæwwæ/ 'he strengthened'	/qæqæ/ 'croaking sound'	/qælæb/ 'he turned upside down'
/qæjjæd/ 'he arrested'		
/qæŠŠæ/'straw'		
/mæquulæ/ 'saying'		
/qilææʕ/'castles'		

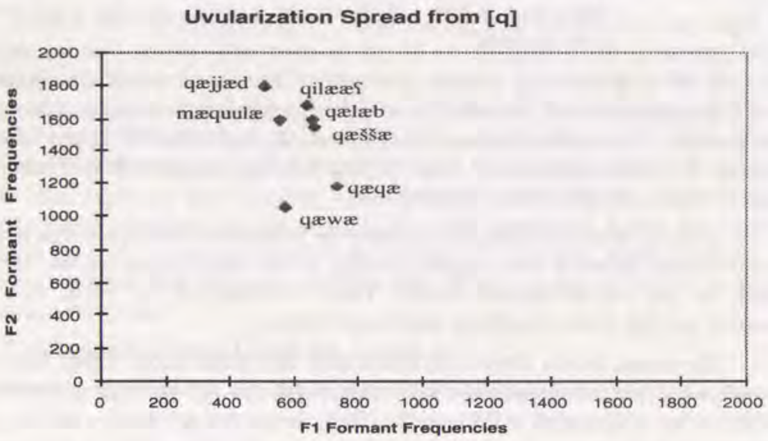
3.4 Procedure

The procedure that was used was exactly the same procedure that was used in the first experiment.

3.5 Results

In this section I will discuss only the F2 results. However, the Fl results are also given for reference. Figure (3) below demonstrates the mean values of the first and second formants of the final low vowels for the five repetitions of each one of the tokens. For the first five words, /qæwwæ, qæjjæd, qilææʕ, mæquulæ, qæŠŠæ/, which are condition 1, we illustrate the results of the second vowel. For /qæqæ/, which is condition 2, we illustrate the results of the first vowel, and for the last word /qælæb/, which is condition 3, we show the results of the second vowel.

Figure 3: uvularization spread from the uvular /q/



In order to get an idea about the difference between the uvular and the uvularization spread, we can compare the F2 results of low vowels that are preceded and followed by these gutturals. The mean of the five repetitions of

each of the words /bæṭæṭæ/ and /ʔuṭæṭ/ in the first experiment have a mean of 1137.3 Hz. The five repetitions of the words /qæqæ/ have a mean of 1187.6 Hz. Thus, the spread from a uvularized segment is stronger than the spread from the uvular /q/. The low vowels following uvularized segments have lower F2 frequency than the low ones following uvulars. A statistical test is needed to tell whether this difference is significant or not.

If we compare the spreading from uvular and uvularized segments to the second vowel we can see that the F2 of the low vowel in the uvular environment is rather high in comparison with the F2 of the low vowel in the uvularized environment. For instance, the F2 mean of the second vowel in the five repetitions of /qælæb/ is 1584.2 Hz. In comparison the mean of the second vowel in the five repetitions of /ṭælæl/ and /ḍællæk/ is 1225.2 Hz. Thus, the F2 of the second low vowel in the uvular enivronment is quite high. However, it is still not as high as a plain vowel, and that is why impressionistically it could be distinguished from a plain vowel. A plain vowel, as we saw earlier, is about 1650 Hz (see Figure 1). Thus, the effect of the RTR articulation of the uvular could be heard on the second vowel, but it is not as strong as it would be if the trigger is a uvularized segment.

To know if the high segments are blocking uvularization spread from the uvular or not, we can say that if the low vowel following the high segment was higher than 1600 Hz, then that vowel is a plain vowel. Below, we will discuss the F2 results of the low vowels following each of the high segments.

Looking at condition 1 in Figure 3, one can notice immediately that there is variation in the results of the F2 mean values of these second low vowels. The mean for the low vowel after the /w/ is 1057.6 Hz. Obviously, this is a very low value. Perhaps a factor in obtaining this low F2 value is the rounding effect of the /w/. As for the low vowel following the /uu/, its F2 was 1586.4 Hz. Since this is still lower than 1600 Hz, one might think it is affected by uvularization. However, if we go back to inspect the individual mean values of each one of the five repetitions of the word /mæquulæ/, one will find that there is some variation. Three of these utterances had an F2 above 1600 Hz, and two were below 1550 Hz. These values might be explained as follows: The low values below 1550 Hz could be a result of the V-to-V coarticulation effect of the rounded vowel, or they could be low because spreading is optional in the same way it was for the word /tæfḍiilææt/. The values that are higher than 1600 Hz could be high because the high vowel /uu/ is blocking uvularization spread from the /q/.

As for the F2 values of the low vowels following the /i/ and /j/, they are both above 1670 Hz. Moreover, each one of the repetitions of each of the two words were all also very high. Hence, these two segments seem to block the spread.

Finally, we come to the F2 values of the low vowel following the /Š/, which was 1546.4 Hz. This value is very close to the mean value of the low vowel following the plain consonant in condition 3 for the word /qælæb/. Moreover, the values of their repetitions are also very similar. Therefore, we come to the conclusion that there is a slight effect of uvularization spread across the high segment /š/.

The conclusion is that uvularization spread from a uvular is not as strong as the uvularization spread from a uvularized phoneme. Moreover, its strongest effect could be heard on the vowel immediately following it. Its effect on the second syllable is much weaker than the effect of a uvularized phoneme (as in the F2 frequencies of /qælæb/ in Figure 2 for the first vowel, and in Figure 3 for the second vowel). This raises a good question, namely, why would the uvularization spread from the secondary uvularized segments be stronger than from the primary uvular /q/? One possible explanation might be because secondary uvularization is contrastive with the plain alveolars. In comparison, the uvular is not contrastive with another segment that has the same place of primary articulation. Therefore, since for the secondary uvularized segments, uvularization is their major feature, they would tend to have a stronger effect on the neighbouring segments. In comparison, for the uvular, uvularization spread might not be a major feature because they do not have a contrastive counterpart. Therefore, the effect of the uvular is less.

This brings up another point: RTR spreading is categorical and gradient. In some segments, like the secondary uvularized segments, it is stronger than in the uvular. Moreover, as we saw from the results of the secondary uvularized phonemes and the uvular, the farther away one gets from the segment, the weaker would the effect of uvularization be. This effect is much more apparent with /q/ than with a secondary uvularized segment. Thus, the vowel that is next to the uvularized phoneme would have a lower F2 than the segment which is farther away.

Finally, the high segments in Ammani Arabic that are blocking the RTR spread from the uvular are the high [-consonantal] segments (other than /w/). High consonantal segments do not block the spread. Thus, /i, uu, j/ block the spread from the uvular, while /š/ does not. There are no blocking segments with uvularization from a secondary uvularized segment.

4. Conclusion

In this paper the left-to-right uvularization spread was examined in the dialect of Jordanian Arabic. When the trigger is a uvularized consonant, such as /ṭ, ḍ, ṣ, ẓ/, uvulariztion spreads throughout the whole word. When there are suffixes, uvularization also spreads into them, the exception is only the suffix *-ææt*. In the latter, spreading is optional when the stem does not end in a uvularized phoneme, as in the case of /tæfḍiilææt/. Furthermore, none of the high segments /ii, uu, š, ž, j, w/ block the rightward spreading of uvularization. The high segment that most affects the F2 of the low vowel in the uvularizd environment is the vowel [i]. However, [i] is not a blocker because there is a significant difference between the low vowel following an [i] in the uvularized environment and the one in the plain coronal environment.

As for the uvulars, the only uvular segment that this dialect uses is the voiceless stop /q/. The phonemes /χ/ and /ʁ/ that are uvular in many Arabic dialects are most probably velar in Jordanian Arabic. Therefore, these segments do not affect the neighbouring vowels as the uvular does.

Concerning the uvular /q/, it has a strong coarticulation effect on the neighbouring vowel, but it is still not as strong as uvularized consonants. Moreover, the segments that we found to be blocking this spread are the high [-consonantal] segments /i, uu, j/.

The results reported here remain only suggestive rather than definitive about the articulatory movements, because they are based only on spectrographic analysis. A better method would be to measure directly the articulatory movements to study the shape of the vocal tract. The spectograms cannot detect the small degrees of backing that happen as a result of uvularization from a distance. Furthermore, the results in this paper cannot be generalized to Jordanian Arabic in general because only one subject was used.

NOTES

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The term uvularization has been suggested by McCarthy 1994 and Czaykowski-Higgins 1987. It has also been adopted by Shahin 1996. In the literature on Arabic Linguistics, this term has been known as emphasis, velarization, and pharyngealization

Rose 1996 uses the feature RTR to account for both the constriction in the pharynx and the retraction of the tongue root. Thus, pharyngeals have an RTR feature like the uvulars and the secondary uvularized segments. I believe that it is crucial to distinguish between the constriction of the pharynx gesture and the retraction of the tongue root, because the latter could spread uvularization but not the former.

The reader is encouraged to read Davis's 1995 paper for a detailed account on the feature geometry.

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