AN ACOUSTIC STUDY OF FRICATIVE-TO-VOWEL COARTICULATION IN ARABIC

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Abstract:

This study examines th carryover coarticulatory effecrs of consonantal context upon the acoustic characteristics of voqwla in Arabic. Five speaders read a list of 65 ev:c syllables containing various initial fricatives, five long vowels, and either final voiceless or voiced alveolar stop consonants. Formant frequency analysis have shown that fricative consonants induced significant coarticuatory effects on the F2 steady state frequency of the variation varies significantly as a function of fricative place of articulation. The degree of fricative-to-vowel coarticulation appears to be related to the amount of articulatory constraint on the tongue activity during the production of fricativeee consonant. Thus the large amount of F2 transition may reflect the antagnoistic demand on the articulatory movements during the production of fricative-to-vowel sequence as in emphatic or pharyneal fricatives andfront high vowels combinations, whereas therelatively small amount of F2 transition may reflect the complementary devand on the articulatory movements as in the sequence of alveolar or palatal fricatives and front high vowels. The insignificant F2 transition variation in the sequence of labio-dental or glottal fricative and vowel may be interpreted to mean neutral demand on the articulatory movements.

Introuction

Studies on the acoustic characteristics of vowels across languages have revealed that the abstract vowel phonemes have arange of phonetic variants across segmental and prosodic contexts. Vowel formant variation has been of particular interest. Vowel quality is usually described by its acoustic information of the first two formant frequencies.

House and Fairbanks {1953} studied te influence of consonant environment upon the secondary acoustical characteristics of vowels in American English. They found that the fundamental frequency of vowels varied significantly in respose to changing consonant environment.

Stevens and House {1963 investigated the formant frequency of 8 vowels and 14 consonants that can appear both initially and finally in American English cvc syllables. They found that consonantal context causes systematic shifts in the vowel formant frequencies depending upon the place of articulation of the consonant, its manner of articulation, and its voicing characteristics. The shifts in F1 value of vowels toward a neutral configuration correspond to an increase in F1 for close vowels and decrease for open vowels. Frot vowels in the environment of labial and postdental consonants show downward shift in the values of F2, no shift for velar consonant environment. Back vowels show upward sift in the value of F2 in the postdental consonant environments.

Lindblom {1963} examined the extent to which formant frequencies in the Swedish vowels reach their target values as a function of vowelseqgent duration. He found that vowels did not reach the target values but they wee modified and reduce in consonantal context.

Öhman {1966} reported that the formant frequencies of the initial vowel in vcv Swedish and English utterances are influenced not only by te medial consonant but also by the nonadjacent vowel.

Broad and Fertig {1970} measured the frequencies of the first three vowel formants in cvc syllable nuclei in American English. They found that the influence of both initial and final consonants are highly significant throughout the vowel.

In their study of vowel reduction Ohde and Sharf {1975} established vowel targets for American English vowels on the basis of spectrographic measurements of F2 from the isolated vowels and compared them with the vowels in context. They found vowel reduction for combined hvcv and cvhv utterances was somewhat greater than for symmetrical cvcv utterances.

Recasens {1987} studied the coarticulatory effects in F2 frequency for Catalan and Spanich vcv sequences, and found that the anticipatoy coarticulation effects appear to be primarily associated with the degree of tongue dorsum constraint upon initial vowel, the extent of carryover coarticulatory effects is dependent on the requirements on the tongue dorsum activty for the entire cv gesture.

One of the purposes of the present investigation is to find out whether the spectral characteristics of the steady state portions of vowels in the Gulf Arabic Dialect spoken in the United Arab Emirates {henceforth GAD} in monosyllabic words vary systematically as a function of the neighbouring fricative consonants. There are phonological and phonetic differences between Arabic and Indo-European languages in particular, and between languages in general. However, that might lead one to postulate cross-language differences with respect to the effects of consonsnt context on the target formant frequency of vowels. Schouten and Pols {1979} reported that the steady state portion of Dutch vowels was found not to vary systematically with consonantal context, but the cv and, to a lesser extent, the vc transitions turned out to combine into pattern that was quite consistent over speaders and conditions.

A second purpose of the present investigation is to measure and describe, in acoustical terms, any regularities in the transitions from fricatives to vowels in the tested utterances. Transitions are usually seen as rapid shifts in the frequency position of the vowel formants where vowel and consonant join and are typically most marked for the F2 {Cooper et al, 1952}.

Studies of natural and synthesized speech have shown that the transitions between the consonant and the steady state portion of the vowel provided important cues for the perception of vowels and consonants. Heinz and Stevens {1961} exposed thier listeners to isolated friction {constant duration of 200 ms}, isolated friction plus the steady state portion of {a}, and friction plus transition plus vowel. On the basis of fricative cues alone, listeners reliably sorted their response into three groups: {s} for low frequency poles, {s} for mid frequency poles, and {f-o±} for high-frequency poles. Adding the synthetic vowel to these friction portions still resulted in {f-o} confusion. They indicated that F2 transition seemed to be a necessary cue for distinushing between these two consonants.

Sharf and Hemeyer {1972} used cv - and vc- stimuli from which the consonant portion had been deleted. They found that vowel formant transitions provided sufficient perceptual cues for fricative consonant identification.

Kuehn and Moll {1972} progressively deleted portions of the consonants and transitions in syllables consisting of fricatives or nasals followed by a vowel on either side of the cv transitions. They found that listenes were able to identify most consonants and all vowels above chance level even though the steady state portions had been deleted.

Ostreicher and Sharf {1976} presented portions of cv, vc, cvc and vcv utterances to American subjects to identify the deleted preceding or following sounds. Subjects were able to determine the tongue height and tongue advancement features of vowels from consonants.

Jenkins et al {1983} and Strange et al {1983} reported that the steady state portion of the vowel is not necessary for good vowel identification. They excised the relatively steady state portion from natural vowels spoken in cvc syllables, and obtained high degrees of accuracy when only the initial and final transitions and relative timing of these portions were left intact. Identification accuracy for these "vowelless" syllables was equal to or greater than that for the steady state portions extracted from the syllables.

MATERIAL AND PROCEDURE

The linguistic material consisted of 65 cv:c syllables. Arabic possesses a phonotactic constraint which limits the monosyllabic words to cv:c or cvcc structures {Swadesh', 1973; Flege', 1981}. In order to separate the influence on the syllable nucleus that are attributable to the initial consonant from those attributable to the final consonant only various initial consonants are examined in the context of the similar final consonants. In fact, MacNeilage and DeClerk {1969} reported that the cv unit is a more cohesive than the vc unit on the basis of greater coarticulation effects of the initial consonant on the medial vowel, than of the final consonant on the medial vowel. Their results support Kozhevnikov and Chistovich {1965} who suggested that the cv syllable is the basic unit of articulation. Similarly Recasens {1985} has shown that the magnitude of carryover coarticulatory effects is greater than anticipatory effects in Catalan.

In each cv:c syllable the initial consonant represents one of the following GAD fricative consonants: {f, e, o, o, s, s, z, s, x, h, , h}, the vowel one of the following long vowels: {i:, e:, a:, o:, u:}, and the final consonant represents either voiceless or voiced alveolar stop consonants. Our selection was based on the wish to make the test material as representative as possible of all GAD fricative-to-vowel sequences. However, by using real words it was not possible to have a uniform set of fricatives with each long vowel cluster, especially with the vowels {e:, o:}, therefore 29 cv:c nonsense syllables were used to fill the gap, but all these nonsenes syllables conform to the phonology of Arabic.

Five native speakers of GAD took part in this experiment. Each speaker was asked to read the word from individual cards presented by the experimenter. Cards were arranged in random order, all tokens were printed on the cards using normal Arabic orthography. Subjects were told to produce each token five times at a speaking rate they considered to be representative of their normal conversational speech. The speech material was recorded in a sound-treated room on a professional-quality portable cassette tape recorder {Sony model TCD5M} using an electrect condensor microphone positioned about six inches from the talker's mouth. The recordings were processed at the University of Texas Speech Laboratory, they were digitized at a sampling rate of 10 KHz, after preemphasis and low-pass filtering. The frequencies of vowel formants were estimated using linear predictive coding {LPC} analysis on a VAX computer.

The segmentation criteria for the vowels and fricative consonants boundaries are similar to those employed by Peterson and Lehiste {1960}, and Al-Ani {1970}. The vowel portion of each cv:c syllable was divided into two segments: {1} the transition from the initial fricative consonant to the steady state part of the vowel, {2} the steady state part of the vowel.

RESULTS AND DISCUSSION

Tables {1},{2} and {3) show the carryover coarticulatory effects of initial fricative consonants on the steady state and formant transitions of the following long vowels in GAD. It is assumed that the average means of the vowel formant frequencies in various fricative contexts will capture at best the one-to-one mapping relationship between the underlying phonemic representations and their corresponding articulatory gestures. Therefore, it is hoped that, the comparison of average means with the mean of individual fricative will provide us better insight to the magnitude of consonantal effects on the target fromant frequencies of vowels. The average means of the vowels steady state F1 and F2 frequencies as a function of various fricatives context is as follows: for the vowel {i:} the average mean of F1 is 330Hz {SD 35}, F2 2562Hz {SD 112}; for the vowel {e:} the averae mean of F1 is 472Hz {SD 35} F2 is 2322Hz {SD 154}; for the vowel {a:} the avergae mean of F1 is 729Hz {SD 31}, F2 1512Hz {SD 150}; for the vowel {o:} the average mean of F1 is 453Hz {SD 36}, 2F 898Hz {SD 84}; and for the vowel {u:} the average F1 is 368Hz {SD 24}, F2 755Hz {SD 50}.

Table (1). Means and standard deviations (in Hz) of the low vowel [a:] F1and F2 frequencies in various initial fricatives context.

Token	F1 frequency				F2 frequency			
	onglide		steady state		onglide		steady state	
	m	SD	m	SD	m	SD	m	SD
fa:t	712	16	773	12	1364	20	1470	37
θa:t*	742	12	781	14	1545	18	1576	46
ð̌a:t	710	21	758	17	1636	42	1682	23
ð̣̌a:t	646	9	682	15	985	39	1183	52
sa:d	636	25	712	10	1727	21	1667	24
ṣa:d	667	18	685	19	939	37	1258	20
za:d	683	11	716	13	1736	47	1636	54
ša:t	685	20	715	24	1652	42	1480	46
xa:t*	768	7	727	11	1324	56	1515	36
ɣa:t	786	15	740	14	1318	29	1500	19
ḥa:d	758	26	712	17	1384	38	1545	45
ʕa:d	788	31	758	21	1403	44	1655	54
ha:t	697	14	716	18	1318	37	1485	48

* nonsense cv:c syllables.

Table (2). Means and standard deviations (in Hz) of the front vowels [i:, e:] F1 and F2 frequencies in various initial fricatives context.

Token	F1 frequency				F2 frequency			
	onglide		steady state		onglide		steady state	
	m	SD	m	SD	m	SD	m	SD
fi:d	318	31	321	26	2571	46	2621	48
θi:t*	320	14	313	21	2182	28	2592	37
ði:t*	305	18	301	16	2045	44	2576	21
ð̣i:t	394	12	318	17	909	36	2273	41
si:t	360	6	348	11	2212	27	2576	45
ṣi:t	424	12	318	18	915	43	2379	32
zi:d	319	24	316	11	2242	24	2591	39
ši:d	310	9	303	11	2424	44	2652	47
xi:t*	373	17	305	15	1924	41	2576	30
ɣi:t*	411	21	312	20	2167	31	2591	30
ḥi:d	492	13	386	10	1970	38	2561	20
ʕi:d	505	20	418	28	1955	43	2681	40
hi:t	341	17	326	24	2606	57	2636	48
fe:t*	424	8	426	5	2315	23	2424	37
θe:t*	450	12	424	10	1818	46	2409	56
ðe:t*	379	9	425	15	1924	43	2410	43
ð̣e:t*	576	13	485	10	955	21	2179	18
se:d	475	18	434	21	2061	13	2319	27
ṣe:d	561	5	485	12	818	10	1894	28
ze:t	515	21	500	18	2159	21	2394	23
še:t*	519	23	515	22	2091	48	2470	51
xe:t*	621	16	485	13	1864	31	2318	35
ɣe:t*	515	18	481	12	1833	46	2258	50
ḥe:t*	636	14	485	19	1803	41	2273	21
ʕe:t*	652	26	530	17	1870	27	2378	20
he:t	485	18	495	11	2212	20	2455	44

One the one hand, comparing the average mean of F1 steady state of the vowel {i:} with the individual fricative context mean it appears that no systematic variation has been induced on F1 {the range does not exceed 50 Hz} as a function of fricative place of articulation. The pharyngeal fricatives show consistent increase in F1 frequency within the range of 100 Hz. Similarly, the F1 steady state of the vowel {e:} shows no significant varition as a function of fricative place of articulation. Only the

Table (3). Means and standard deviation (in Hz) of the back vowl [o:,u:] F1 and F2 frequencies in various initial fricatives context.

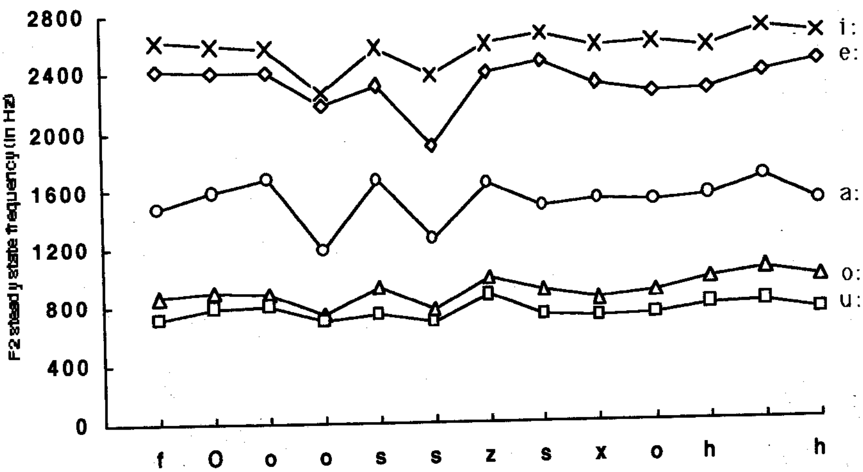
Token	F1 frequency				F2 frequency			
	onglide		steady state		onglide		steady state	
	m	SD	m	SD	m	SD	m	SD
fo:t*	439	14	424	8	888	24	863	27
θo:t*	394	9	413	13	1121	48	898	25
ð̆o:t*	452	12	460	16	1197	32	879	29
ð̣o:t*	495	6	410	5	561	18	742	34
so:d	394	17	439	10	1470	40	924	37
ṣo:t	486	14	441	21	673	37	773	29
zo:d	401	15	428	26	1470	13	993	26
šo:t	394	7	430	18	1380	40	894	43
xo:t*	500	24	485	20	902	15	839	30
ɣo:t*	512	11	469	26	909	28	879	18
ḥo:t*	636	31	515	16	1091	27	876	46
ʕo:d	652	18	518	10	1242	18	1030	26
ho:t*	455	21	456	28	1061	26	982	35
fu:t	352	16	348	24	735	26	716	32
θu:t*	364	10	333	8	1424	42	788	26
ð̆u:t*	361	12	336	12	1470	18	803	31
ð̣u:t*	374	24	404	18	667	40	705	36
su:d	350	32	348	17	1425	36	742	18
ṣu:t*	364	19	368	14	682	31	692	45
zu:d	379	16	385	24	1712	18	864	27
šu:t	365	21	365	29	1409	31	727	40
xu:t*	376	31	380	37	768	48	712	28
ɣu:t*	382	18	379	11	778	29	727	17
ḥu:d	348	27	346	20	1121	20	796	42
ʕu:d	424	19	396	16	1167	37	803	20
hu:d	394	14	395	17	788	18	742	36

voiced pharyngeal fricative {?} shows consistent increase in F1 within the range of 75Hz. The vowels {a:, o:, u:} also show no significant variation in their F1 steady state frequency in the vicinity of fricative consonants, but once again the pharyngeal fricatives induced systematic increase in the vowel {o:} F1 frequency within the range of 70Hz.

On the other hand, fricative consonants induced systematic large coarticulatory effects on the F2 steady state frequencies of the following vowels. Figure {1} shows the mean values of F2 steady state frequency as a function of preceding fricative place of articulation. A glance at the figure tells us that vowels are shown to differ in their amount of F2 steady state variation. The difference between the highest and the lowest mean values of F2 steady state for each vowel is as follows: {i:} 408 Hz, {e:} 576Hz, {a:} 499Hz, {o:} 288Hz, and {u:} 172Hz. However, the carryover coarticulatory effects did not produce a progressive increase or decrease in F2 steady state freguency of the vowel as the place of fricative articulation moves from anterior to posterior position in the oral cavity, nevertheless the following tendncies emerge:

{1}-F2 steady state frequencies of the vowels are lowered considerably in the vicinity of the emphatic fricatives compared to the values in nonemphatic counterpart fricatives. The amount of F2 steady state lowering induced by the emphatic dental fricative {o} increases in the progression {u:} « {o:} « {e:} « {i:} « {a:}, and by the emphatic alveolar fricative {s} increases in the progression « {u:} « {o:} « {i:} « {a:} « {e:}. The present result is inagreement with the findings reported by Fant {1960} that F2 frequency is inversely related to the degree of tongue backing. The production of emphatic fricatives {o} and {s} involves a primary articulation involoving a narrow constriction between the tip of the tongue and the upper front teeth for the

FIG. (1). Mean values of steady state frequency (in Hz) of the long vowels as a function of preceding fricative place of articulation.



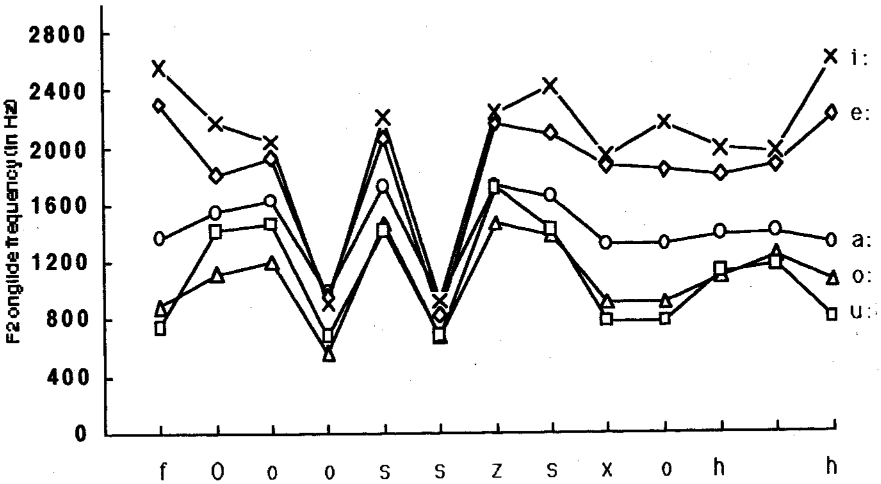
former, and the blade of the tongue and the alveolar ridge for the latter. A secondary articulation involves tongue retraction towards the pharyngeal cavity {Ali and Daniloff, 1972; Al-Gazali, 1979}. The insignificant amount of F2 steady state lowering of the vowel {u:} reflects that this vowel is interinsically back and probably resists further backing of the tongue.

{2} - The degree of lowering in the pharyngeal fricatives construction is also systematically influenced the F2 steady state frequencies of the following vowels. Pharyngeal fricatives in Arabic language are produced by retracting and lowaring the root of the tongue and making a low narrow constiriction with the back wall of the pharynx in the laryngopharyngeal cavity {Delattre, 1971; Ali and Daniloff, 1972; Al-Ghazali, 1979}. The constriction for the voixeless pharyngeal {h} is lower and narrower than for the voiced pharyngeal {?}. In the present data the lowering of {h} constriction caused the F2 steady state frequencies of the vowels to decrease as follows: {i:} 120Hz, {a:} 110Hz, {e:} 105Hz, {o:} 54Hz, and {u:} 7Hz; compared to their mean values preceding the voiced counterpart. The F2 lowering is associated with the size of the oral cavity: the wider the oral cavity, the lower the F2 frequency {Fant, 1966}. Once again the relatively small amount of the F2 steady state lowering of the vowel {u:} shows that back vowels are less sensitive to backing coarticulation effects.

As mentioned earlier a number of studies have shown that the formant transitions between the consonants and the steady state part of the vowel provide important acoustic cues for the perception of vowels and consonants. In the present study fromant transition will be examined to find out any regularities in the upward or downward shift in the values of formant transition as a function of preceding fricative pace of articulation.

The reaults showed no significant carryover coarticulatory effects on the F1 onglide transition for the vowels {i:, e:, o:} in the vicinity of fricative with anterior place of articulation {i.e. dentals, alveolars and palatals}. The amount of F1 transition variation did not exceed 50Hz, and more importantly the variation was inconsistent among tokens repetitions. Consistent with the data reported here, Delattre et al {955} found that the locus of the F1 is identical for {b, d, g}, and suggested that the F1 locus has nothing to do with consonant place of articulation. However, fricatives articulated in the posterior place of articulation {i.e. uvulars, pharyngeals} and

FIG. (2). Mean values of F2 onglide transition frequency (in Hz) of the long vowels as a function of preceding fricative place of articulation.



emphatic fricatives show systematic upward shift in the F1 transition of these vowels. Althought the amount of the F1 transition for the low vowel {a:} did not exceed 50Hz range but it showed consistent upward shift after fricatives with posterior place of articulation and dwnward shift after fricatives with interior place of articulation. The vowel {u:} showed hardly any movements in the F1 transition as a function of ficative place of articulation. El-Halees {1985} reported that the F1 transition plays a major role in the distinction between the uvular and pharyngeal place of articulation in Jordanian Arabic.

Figure {2} shows the mean values of the F2 onglide transition of the vowels as a function of preceding fricative place of articulation. A glance at the figure shows large amount of variations in the F2 onglide transition but the degree of varition varies amoung fricatives with different places of articulation. To get better understanding of such coarticulatory constraint let us examine in more details the behavior of the F2 onglide transition before individual fricative:

1. The labio-dental voiceless fricative {f} showed downward shift in the F2 transition of the front and low vowels. The F2 transition mean values decreased as follows {u:} 19Hz, {a:} 25Hz.

2. The dental voiceless fricative {e} showed downward shift in the F2 transition of the vowels: {a:} 31Hz, and {e:} 591Hz. The back vowels showed upward shift in the F2 transition? {o:} 223Hz and {u:} 36bHz.
3. The dental voiceless fricative {o} showed downward shift in the F2 transition of the vowels: {a:} 46Hz, and {e:} 486Hz and {i:} 531Hz. The back vowels showed upward shift in the F2 transition: {o:} 318Hz and {u:} 667Hz.
4. The dental voiced emphatic fricative {o} showed downward shift in the F2 transition of the vowels: {u:} 38Hz, and {o:} 181Hz, {a:} 198 Hz, {:e} 1224Hz and {i:} 1364Hz.
5. The alveolar voiceless fricative {s} showed downward shift in the F2 transition of the front vowels: e:} 258Hz, and {i:} 364Hz. The low and back vowels showed upward shift in the F2 transition: {a:} 60Hz, {o:} 546Hz and {u:} 683Hz.

6. The alveolar voiced freicative {s} showed downward shift in the F2 transition of all vowels: {u:} 10Hz, {o:} 100Hz, {a:} 319Hz, {e:} 1076Hz and {i:} 1464Hz.
7. The alveolar voiced fricative {z} showed downward shift in the F2 transition of the front vowels: {e:} 235Hz, and {i:} 349Hz. The low and back vowels showed upward shift in the F2 transition: {a:} 100Hz, {o:} 477Hz and {u:} 848Hz.
8. The palato-alveolar voiceless freicative {s} showed downward shift in the F2 frequency of the front vowels: {i:} 228Hz, and {e:} 379Hz. The low and back vowels showed upward shift in the F2 transition: {a:} 172Hz, {o:} 486Hz, and {u:} 682Hz.
9. The uvular voiceless fricative {x} showed downward shift in the F2 transition of the vowels: {a:} 191Hz {e:} 454Hz and {e:} 652Hz. The back vowels showed upward shift in the F2 transition: {u:} 56Hz and {o:} 63Hz.
10. The uvular voiceless fricative {b} showed downward shift in the F2 transition of the vowels: {a:} 182Hz, {i:} 424Hz and {e:} 425Hz. The back vowels showed upward shift in the F2 transition: {o:} 30Hz and {u:} 51Hz.
11. The pharyngeal voiceless fricative {h} showed downward shift in the F2 transition of the vowels: {a:} 161Hz, {e:} 470Hz and {i:} 591Hz. The back vowels showed upward shift in the F2 transition: {o:} 115Hz and {u:} 325Hz.
12. The pharyngeal voiceless fricative {?} showed downward shift in the F2 transition of the vowels: {a:} 252Hz,{e:} 508Hz and {i:} 726Hz. The back vowels showed upward shift in the F2 transition: {o:} 212Hz and {u:} 364Hz.

13. The glottal voiceless fricative {h} showed downward shift in the F2 transition of the vowels: {i:} 30Hz, {a:} 167Hz and {e:} 243Hz. The back vowels showed upward shift in the F2 transition: {u:} 46Hz and {o:} 79Hz.

A few tendencies emerge from the carryover coarticulatory effects of the fricative consonants on the F2 onglide transition:

1- All fricatives influenced the front vowels by lowering their F2 onglide frequencies compared to their steady state values in similar context. The F2 lowering for the vowel {i:} decreased in the progression <h <f <s <z <s <e <y <o <h <x <? o s, and for the vowel {e:} the F2 lowering decreased in t he progression <f <z <h <s <s <y <x <h <d <? <e <s <o. The back vowels showed raising F2 onglide transition before all fricatives except emphatic fricative which showed F2 lowering effects. The F2 onglide raising of the vowel {o:} increased in the progression <f <y <x <h <h <? <e <o <z <s <s, and for the vowel {u:} the F2 raising increased in the progression <f <h <y <x <h <? <e <o <s <s < z. The low vowel {a:} showed lowering F2 onglide transition berore all fricatives except alveolar and palato-alveolar fricatives which showed F2 raising effects. The lowering of F2 onglide decreased in the progression e< o< f< h< h< y< x< o< ?< s, and the rasing of F2 onglide increased in the progression s« z« s.
2- The decrease in the F2 onglide frequencies of the high and mid front vowels reflects some tongue lowering induced by the preceding fricatives. According to Fant {1960} F2 frequency correlates with front cavity size and therefore with the degree of tongue raising towards the palate. Wood {1982} found that an increase in the distance between the tongue and the palate at the place of primary constriction for front vowels causes significant decrease in the F2 frequency. The large amount of F2 onglide lowering for the high front vowels in the emphatic context is then understandable since the front cavity size is inhanced by the tongue lowering and retracting for the articulation of the emphatic fricatives. The relatively small amount of the F2 onglide lowering before dental, alveolar and palatal fricatives reflects less demand on the tongue movement during the articulation of these fricatives and the front vowels.
3- The increase in the F2 onglide frequncies of the back vowels reflects some tongue raising induced by the preceding fricatives. The friction constriction for dental, alveolar and palatal fricatives involves tongue fronting and raising towards

the palatal region of the oral cavity which causes some reduction in the front cavity size, thus yeilding acoustically to an increase in the F2 onglide frequency. Wood {1982} reported that advancing the dorsal constriction for {u} from the back or mid soft palate to the front soft palate or to even more anterior region causes a large F2 increase, similar results obtained by Maeda {1990} for the vowel {o}. The emphatic fricatives influenced the back vowels by lowering their F2 onglide transition which reflects that the tongue is somewhat further retracted during the production of the sequence emphatic fricatives plus back vowels. However, the vowel {u:} showed insignificant amount of F2 onglide lowering {less than 50Hz} which indicates that this vowel resists further backing. The carryover coarticulatory effects of the pharyngeal fricatives on the back vowels probably reflects some reduction in the back cavity size, and the small amount of F2 onglide raising before uvular fricatives may reflect that the tongue movement is minimum during the articulation of the sequence uvular fricatives plus back vowels.

4- The increas in the F2 onglide frequencies of the low vowel {a:} in the vicinty of the alveolar and palatal fricatives reflects some tongue raising towards the palatal region of the oral cavity during the formation of these fricative constrictions. Carney and Moll {1971} found that the x-ray data showing more tongue dorsum raising for {a} when it is adjacent to {s} in the sequence {hisa} than when it is adjacent to {v} in the sequence {hiva}. The decrease in the F2 onglide frequency reflects some tongue backing and lowering induced by the preceding emphatic uvular and pharyngeal fricatives.

5- All vowels showed small amount of carryover coarticulatory effects in the vicinity of the glottal fricative and the labio-dental fricative which reflects the nuetral demand on the tongue movement duringthe articulation of these consonants and the following vowels. The production of {h} involves tongue readiness for the articulation of the following vowel, and the production of {f} require no tongue movements.

CONCLUSIONS

The results of the present investigation reveal that the fricative consonants induced carryover coarticulatory effects on the following vowels in the cv:c syllables in GAD. The second formant frequency of the vowels showed significant variation as a function of the preceding fricative place of articulation. In general it appears that the amount of c-to-v coarticulation is inversely related to the degree of fricative articulators involvement in the production of the follwing vowel. Thus, on the one hand, the large decrease in the F2 frequency of the front high vowel in the vicinity of emphatic and pharyngeal fricatives reflects the antagonistic demand on the articulatory movements during the production of such sequences; wheres. the emphatic and pharyngeal fricatives involve lowering and retracting the tongue, the front high vowel requires tongue fronting and raising towards the palatal region of the oral cvity. On other hand, the relatively small decrease in the F2 frequency of the front high vowel in the vicinity of alveolar and palatal fricatives reflects the complementary demand on the tongue movement during the proudtion of such sequences, whereas the articulation of both the consonant and the following vowel involves tongue fronting and raising towards the palatal region.

However, it should be noted that the fricative carryover coarticulatory effects on the vowels can be explained more accurately by means of electropalatography study which provides detailed information on the articulators movement and position during the production of fricative-to-vowel sequence. Apoint which can be considered for future investigation of Arabic fricative consonants. Another point which needs further study is whether native speaker of Arabic language can detect formant transitions in the vowel space as belonging to specific fricative consonants, without those fricative consonants being actually present in speech signal.

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