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Glottal-Deletion and Compensatory Lengthening In Farsi

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Abstract

This study tested whether Farsi exhibits vowel compensatory lengthening. It has been suggested that, in Farsi, compensatory lengthening is triggered by the deletion of glottal consonants in coda position in informal speech (Darzi 1991). As a result, minimal pairs such as [tar] and [tarh] should contrast only with respect to vowel length. A corpus of 90 words of the form CVC, CVCG, CVGC, and CVCC (where V=a vowel and G=a glottal consonant) was recorded, and durations of vowels in different contexts were measured and compared. The results showed that the duration of lax vowels in CVC words and in CVCG/CVGC were significantly different, with the exception of /e/. /e/ might behave differently because it is also the epenthetic vowel most commonly used in loanword adaptation. One surprising result was that, in general, the vowels in CVCC configuration were longer than CVC configuration.

1. Introduction

This study aims at determining whether glottal deletion in Farsi results in compemnsatory lengthening of the preceding vowel. Farsi is a six-vowel system with three lax vowels, /a, e, o/, and three tense vowels,/æ, i, u/. Both traditional grammarians and modern linguists suggest that Farsi tense vowels are longer than lax vowels, and that there are no vowels that contrast only in length (Comrie 1987, Samareh 1977). However, it has also been suggested that Farsi exhibits compensatory lengthening, which is triggered by the deletion of glottal consonants in coda position in informal speech (Darzi 1991). Complex codas are common in Farsi, including clusters with glottal consonants (e.g., /mehr/ 'affection,' /madh/ 'praise'). When these glottals delete, the other member of the cluster remains. This means there could be surface minimal pairs, such as /tær/→ [tær] 'wet' and /tærh/→[tæːr] 'design,' that would contrast only with respect to vowel length.

The current study proceeded in the following way. First, it compared the duration of tense and lax vowels in order to determine whether all tokens (containing either lax or tense vowel) could be analyzed together. This step was accomplished by generating the following hypothesis: H1– "tense and lax vowels have the same duration." This hypothesis was not falsified (discussed in section 3.1); therefore, all tokens were analyzed together. Second, it examined the effect of coda clusters on the immediately preceding vowels to determine whether the increase in the number of consonants in the coda resulted in the shortening of

the vowels. A second hypothesis was formulated: H2– "vowels in CVC[1] and CVCC have the same duration." This hypothesis was falsified, with CVCC words having longer vowels. However, when the vowels, based on their quality, were examined separately, it was found that different vowels behave differently when they precede a coda cluster. The vowels and their behavior are discussed in section 3 of this paper.

In the third step, the study aimed at determining whether a glottal consonant in a coda cluster affected the vowel any differently than other consonants, and whether there were any interacting factors that exaggerated the lengthening of the vowel following a glottal deletion. The logic behind this step is that if the presence of a glottal had a special effect on the vowel, then we would expect its deletion to also have an effect different than other consonants. Since it was important to determine whether the adjacency of the glottal and the vowel is a crucial factor in predicting compensatory lengthening due to glottal deletion, the CVCG (G stands for a glottal consonant) and CVGC words were separately compared to CVCC words. As a result, the following hypotheses were generated and tested: H3– "vowels in CVCC and CVCG have the same duration" and H4– "vowels in CVCC and CVGC have the same duration." H3 was not falsified (discussed in section 3.3.1), but H4 was (discussed in section3.3.2). This means that simply having a glottal consonant in the coda cluster did not affect the vowel. Instead, the adjacency of the glottal to the vowel resulted in the shortening of the vowel – suggesting that glottal deletion is more likely to result in vowel lengthening when the glottal is adjacent to the vowel. Finally, in determining the factors that might interact with the presence of a glottal, the study examined the absence of stress on the syllable that contains the glottal. In this investigation, disyllabic words of the form CVC.CVC were examined. This comparison is not exactly parallel to the earlier comparison of monosyllabic words, but this is because there are no disyllabic words with triconsonantal medial clusters involving a glottal consonant. The stress in monomorphemic words in Farsi is always final. As a result, the stressless syllables used in the study fell into two groups, CVC.CVC and CVG.CVC. Moreover, this comparison would allow us to confirm that the presence of an adjacent glottal resulted in the shortening of the vowel. The following hypothesis was generated: H5– "vowels in CVC.CVC and CVG.CVC have the same duration." While this hypothesis was falsified (discussed in section 3.3.3) as expected based on the falsification of H4, the vowels adjacent to the glottals were lengthened in the disyllabic words. As a result of this opposite effect in CVGC and CVG.CVC words, one might expect an opposite effect in the cases of glottal deletion in these words.

In the final step, the study examined the effect of glottal deletion on the length of the preceding vowel. Based on earlier results regarding the effect of the adjacency of the glottal consonant and the vowel, there were three expectations. First, when the glottal consonant was not adjacent to the vowel, it was expected that the deletion of glottal in a coda cluster would not have any effect on the vowel: H6– "vowels in CVCG and CVC(G)[2] have the same duration." As expected, this hypothesis was not falsified (discussed in section 3.4.1). Second, it was expected that the vowels in CV(G)C would show compensatory lengthening because the CVGC cases showed vowel shortening: H7– "vowels in CVGC and CV(G)C have the

[1] C stands for *consonant*, and V stands for *vowel*.
[2] The parentheses illustrates the deleted segment.

same duration." This hypothesis was falsified (discussed in section 3.4.2), contrary to the expectation that CV(G)C would show compensatory lengthening. Finally, it was expected that CV(G).CVC cases would display vowel shortening since the comparison of CVC.CVC and CVG.CVC words showed that the presence of a glottal consonant in the first syllable resulted in a longer preceding vowel: H8 – "vowels in CVG.CVC and CV(G).CVC have the same duration." This hypothesis was falsified (discussed in section 3.4.3), illustrating that the deletion of the glottal resulted in lengthening of the preceding vowel, and not shortening it as expected based on the results of H5.

2. Methods

Speech samples were collected from six native speakers of Farsi.[3] There were two females and four males who participated, and their ages ranged from 19 to 65. All of the participants were speakers of Tehrani dialect, and non-linguists. The corpus comprised 92 words. The majority of the words contained lax vowels, with only 16 words containing a tense vowel, to allow for a comparison of lax and tense vowels. The words were of the following forms: CVC, CVCG, CVGC, CVCC, CVCCVC, CVGCVC. The list of all the words is given in Appendix 1. The subjects were given a randomized list of words typed in Farsi script, and were instructed to read the words in a colloquial manner as if they were using these words in a conversation with a friend. Each word was read twice. Four subjects' samples were digitally recorded. The other two subjects were recorded onto a tape cassette, and then the samples were digitized.

Waveforms and spectrograms of the recorded words were examined, using PCQuirer software. For every word, the duration of the vowel was measured from either the end of the aspiration of the stops, or the end of the fricative, to the offset of a higher frequency component of the vowel. The aspiration of the initial stop was not included in the measurement, because many of the vowels of interest did not follow a voiceless stop and the exclusion of the aspiration made the collection of measurements more uniform. In cases where the third or fourth formants were no longer visible on the spectrogram, if the second formant was still strong, that portion was included in the duration of the vowel.

3. Formulation of Hypotheses & Results

As mentioned in Section 1, 8 hypotheses were tested. In all comparisons, a t-test ("t-test – paired using means") was performed to test whether there was a reliable difference between items being compared; that is, whether the hypothesis could be falsified. The details of the results of the tests are provided in Appendix 2.

3.1 H1: Tense and lax vowels have the same duration.

This hypothesis was formulated to determine whether the test items that have tense vowel or short vowel could be analyzed together. All the words used in the analysis were of the form CVC. The words used in the analysis are provided in Table 1 on the next page:

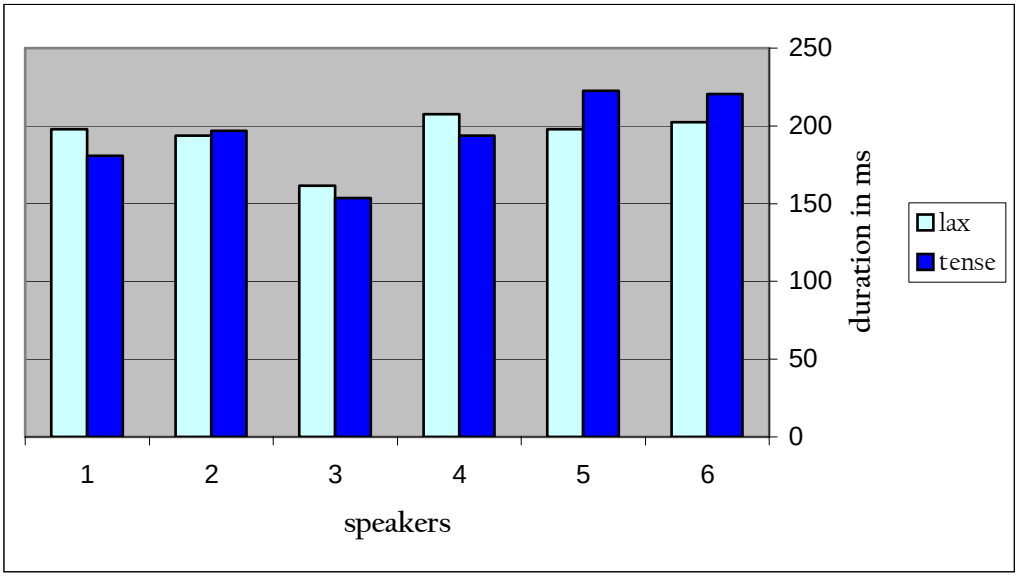
[3] Originally 8 speakers were recorded, but two sets of speech samples were eliminated due to the speech impediment of one speaker, and one speaker's failure in producing any colloquial variants of the stimuli.

Table 1: *Words used in tense/lax comparison*

Tense vowels			Lax vowels		
muʃ	bid	ʃad	bæd	ʃol	ser
kur	sim	bal	bær	bot	mes
sut	zir	bad	mæd	mod	vez
			sæd	qor	
			tæb	bol	
			tær		
			ʃær		

Contrary to the previous literature, the hypothesis was not falsified ($t(5)=0.2$, $p>0.8$), and the durations of tense and lax vowels were not significantly different from each other, as shown in Figure 1 below. Therefore, all tokens were analyzed together for the rest of the study.

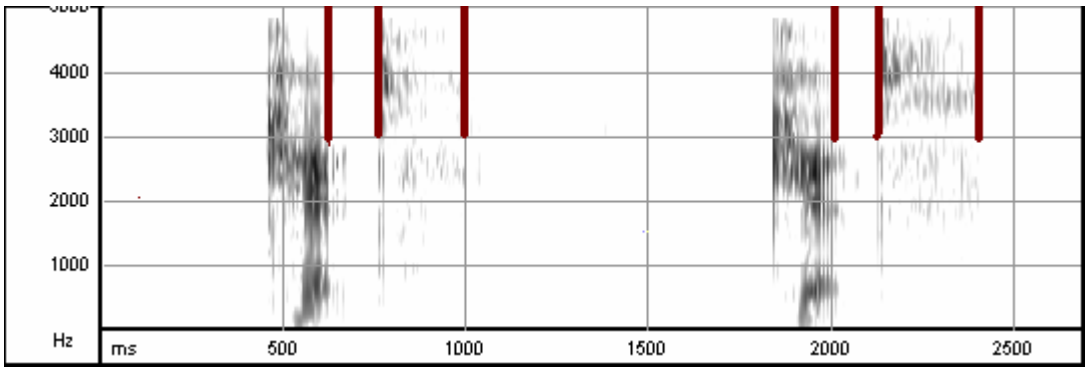
Figure 1: *Durations of tense and lax vowels*
(mean tense: 194.65ms, mean lax: 193.5ms; not significantly different)



3.2 H2: Vowels in CVC and CVCC have the same duration

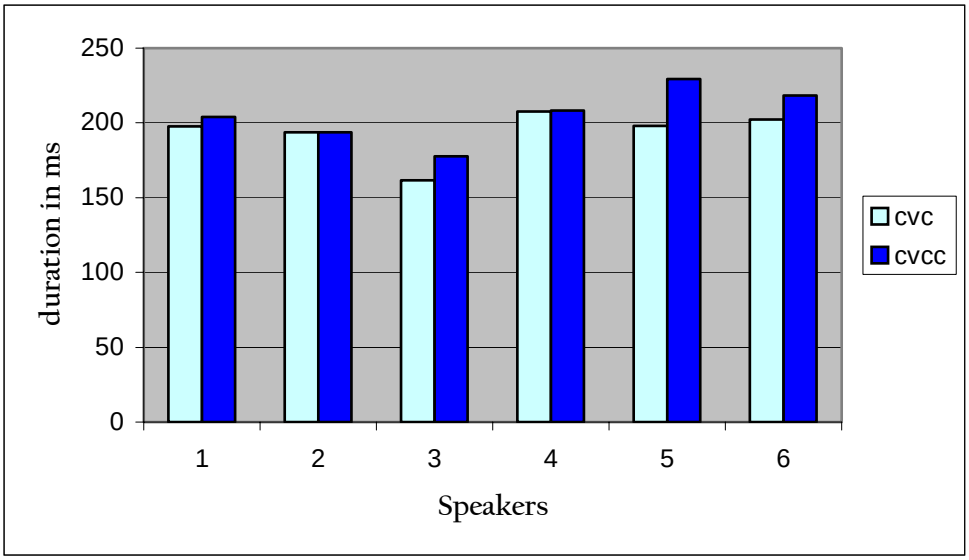
Before comparing words containing deleted and preserved glottals, a hypothesis was formulated to determine whether vowel length remains constant across syllables of different lengths, or there is pre-cluster shortening in closed syllables: H2– vowels in CVC and CVCC words have the same duration. In almost all of the CVCC words, both members of the coda cluster were visible and segmentable. The spectrogram below shows both tokens of /ketf/ 'shoulder' in which the coda consonants are visible:

Figure 2: *Two tokens of /ketf/*



At first glance, the hypothesis was falsified. Vowel length in CVC and CVCC words, as seen in Figure 3, showed significant difference (t(5)=2.42, p~0.05).

Figure 3: *Mean durations in CVC and CVCC words*
CVC:193.5ms, CVCC:205.25ms (significantly different)



Surprisingly, the duration of the vowel in CVCC syllables was longer than in CVC syllables. This means that not only there is no pre-cluster shortening in Farsi, but there is pre-cluster lengthening, which is unexpected. The list of the words and the vowel durations for each speaker are provided in Table 2:

Table 2: *List of CVC and CVCC words compared*

CVC			CVCC		
muʃ	bæd	ser	sedr	bænd	moft
kur	bær	mes	mesr	bæzr	kord
sut	mæd	vez	ketf	mærd	toxm
bid	sæd	bol	ʃerk	særd	mord
sim	tæb	ʃol	bekr	qærz	
zir	tær	bot		ʃærm	
ʃad	ʃær	mod			
bal		qor			
bad					

However, when different vowels are examined separately, the hypothesis was not falsified for every vowel group. First, vowel durations in CoC and CoCC were compared. The list of words is give below:

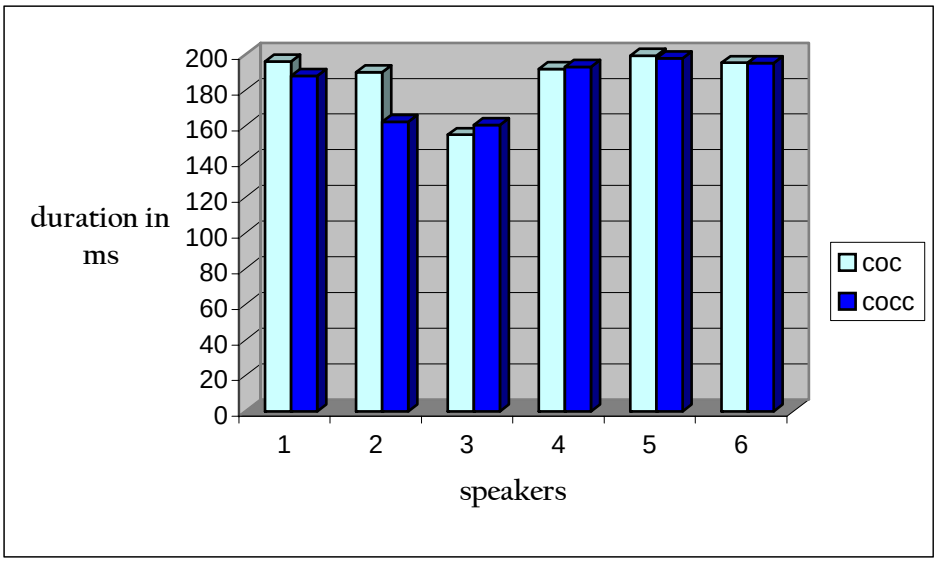
Table 3: *List of CoC and CoCC words compared*

CoC	CoCC
bol	moft
mod	mord
bot	toxm
ʃol	kord

The comparison showed that the difference in vowel duration in the two syllable types, CoC and CoCC, was not significant ($t(5)=1.05$, $p>0.3$).

Figure 4: *Mean duration of /o/*

CoC: 188 ms, CoCC: 182.9ms (not significantly different)



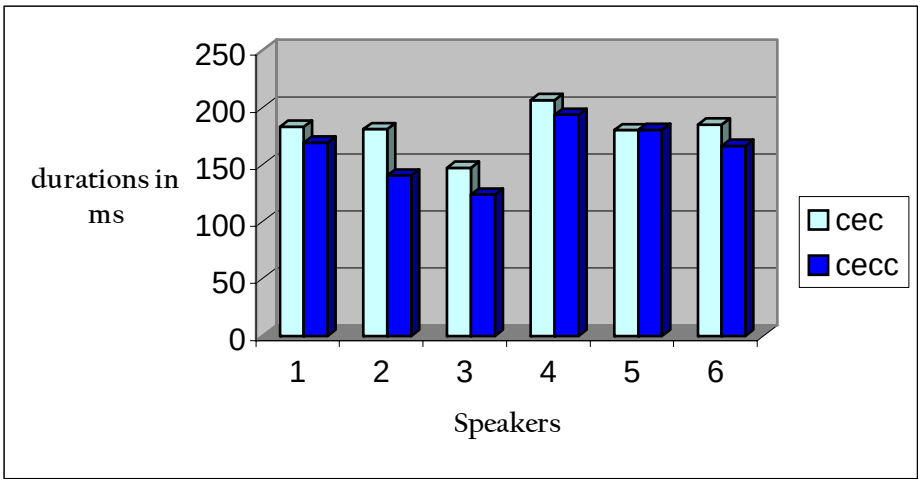
Second, vowel durations in CeC and CeCC were compared. The list of words is given below:

Table 4: *List of CeC and CeCC words compared*

CeC	CeCC
ser	sedr
mes	mesr
vez	ketf
	ʃerk
	bekr

The comparison showed that the difference in vowel durations in the two syllable types, CeC and CeCC, were not significantly different ($t(5)=3.2$, $p<0.03$). While the difference was not statistically significant, CeC had a longer vowel than CeCC. As a result, we could conclude that this vowel, /e/, shows pre-cluster shortening. Figure 5 below shows that mean duration of the vowel across subjects:

Figure 5: *Mean duration of /e/*
CeC: 180.6ms, CeCC: 162.4ms (significantly different)



Third, vowel durations in CæC and CæCC were compared. The list of words is given below:

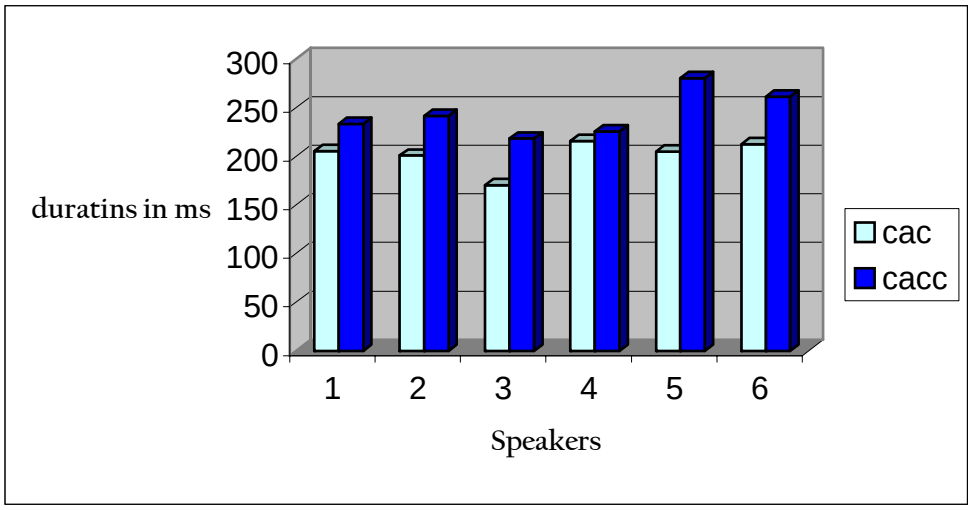
Table 5: *List of CæC and CæCC words compared*

CæC		CæCC	
sæd	bæd	bænd	særd
ʃær	bær	bæzr	ʃærm
tær	mæd	mærd	qærz
tæb			

The comparison showed that the difference in vowel durations in the two syllable types, CæC and CæCC, is significant ($t(5)=4.6$, $p<0.006$). However, this difference was in the opposite direction of /e/, such that the vowel in CæCC was significantly longer than in CæC, as illustrated in the Figure 6 below:

Figure 6: *Mean duration of /æ/*

CæC: 201.5ms, CæCC: 243.4ms (significantly different)



While it remains mysterious as to why each vowel shows a different behavior[4], it can be concluded that there is no general pattern of vowel duration as a function of syllable type. As a result of the absence of pre-cluster shortening, one would not expect to find compensatory lengthening in Farsi.

3.3 Glottal consonants behave like other consonants

In order to examine whether the presence of a glottal consonant in coda cluster affects the vowel differently than the presence of other consonants, the following hypotheses were formulated and tested.

3.3.1. H3: Vowels in CVCC and CVCG words have the same duration

In order to determine whether the presence of a phonetic glottal consonant in the coda has an effect on the duration of the preceding vowel, the hypothesis "vowels in CVCC and CVCG words have the same duration" was tested. The spectrograms were first examined in order to confirm that the glottal consonants in the CVCG words used for this analysis were not deleted.

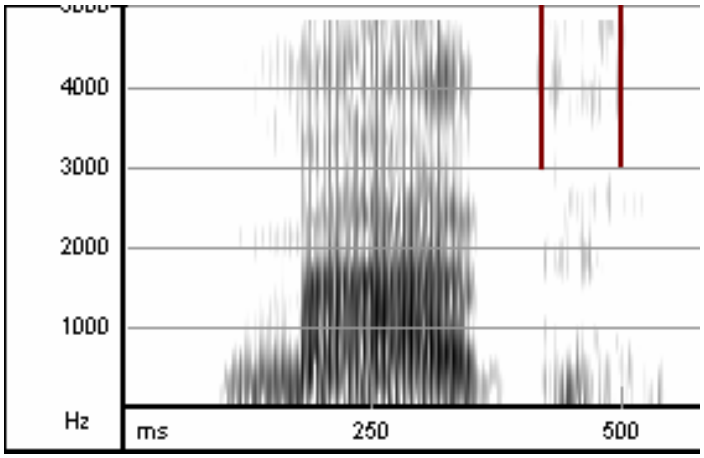
[4] One could speculate that /e/, which is also the epenthetic vowel, is the shortest vowel and resists lengthening, but the different behaviors of /o/ and /a/ remain unsolved.

Table 6: *List of CVCC and CVGC words*

CVCC			CVCG		
sedr	bænd	moft	zelʔ	ʃærh	solh
mesr	bæzr	kord	tæbʔ	tærh	sobh
ketf	mærd	toxm	qælʔ	mædh	robʔ
ʃerk	særd	mord	ʃærʔ	ʃæmʔ	xælʔ
bekr	qærz	ʃærm			

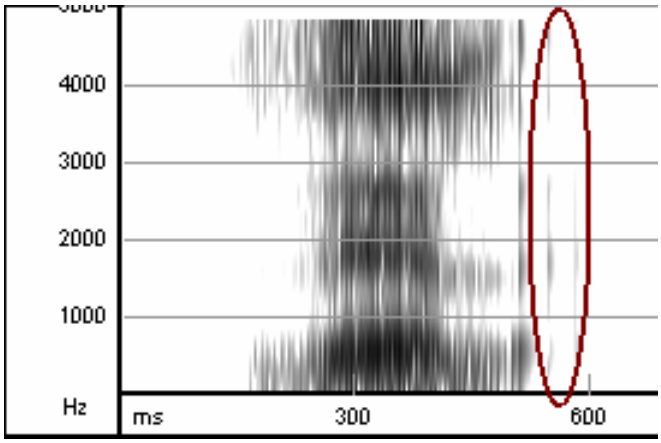
For the glottal fricative, /h/, it was generally possible to segment the consonant on the spectrogram (even though it was weak in some cases). The spectrogram below shows one token for /mædh/ 'praise,' in which the fricative is visible and segmentable from the preceding consonant.

Figure 7: A token of /mædh/



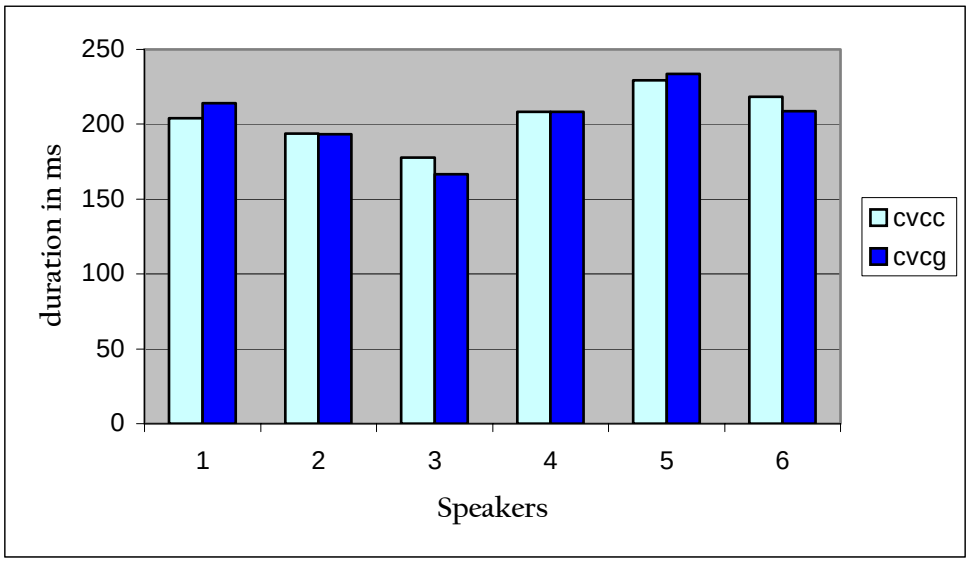
Similarly, for the glottal stop, /ʔ/, following a consonant at the end of the word, in many cases the release of the glottal was easy to spot on the spectrogram. The figure on the next page illustrates that point in [zelʔ] 'side':

Figure 8: *A token of /zelʔ/*



Comparing the vowel durations in the two syllable types, CVCC and CVCG, showed that the stated hypothesis was not falsified. The vowel durations in CVCC and CVCG words were not significantly different from each other ($t(5)=0.3$, $p>0.7$). In fact, the mean value for the two groups was almost identical. This means that if the glottal consonant is not adjacent to the vowel it has no effect on the length of that vowel, as seen in Figure 9; therefore, we would not expect the deletion of the glottal to have an effect on vowel length, either.

Figure 9: *Mean durations in CVCC and CVCG words*
CVCC: 205.25ms, CVCG: 204.1ms (not significantly different)



3.3.2. H4: Vowels in CVCC and CVGC words have the same duration

Similarly to section 3.3.1., in order to determine whether the presence of a phonetic glottal consonant in the coda has an effect on the duration of the preceding vowel, the stated hypothesis "vowels in CVCC and CVGC words have the same duration" was tested. This hypothesis examines whether, in addition to the presence of the glottal consonants, the proximity of the glottal consonant and the vowel has an effect on the duration of the vowel.

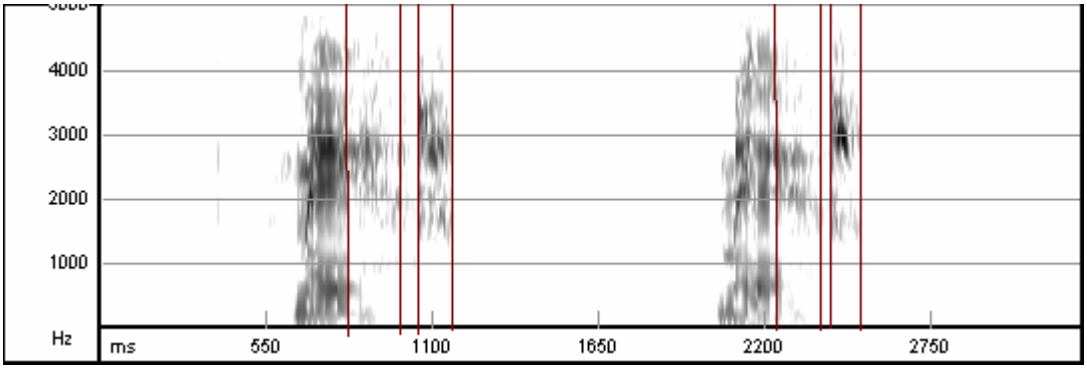
Table 7: *List of CVGC used in comparison with the CVCC words (listed in Table 6)*

CVGC				
sehr	bæʔd	mæhd	boʔd	bohl
mehr	qæʔr	sæhl	roʔb	fohʃ
feʔl	bæʔd	pæhn	bæhr	boht
ʃeʔr	læʔl	ʃæhr	qæhr	mohr

The spectrograms were examined in order to confirm that the glottal consonants in CVGC words used for this analysis were not deleted. In some cases the strong effect of the glottal

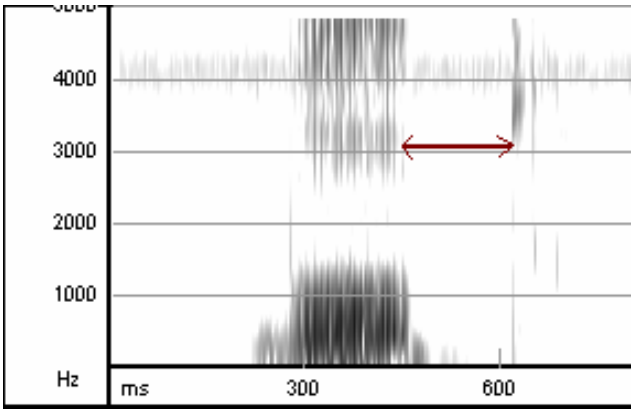
(e.g., devoicing of /r/ and the following breathiness in /mehɾ/ 'kindness') was visible, as illustrated in Figure 10:

Figure 10: *Two tokens of /mehɾ/*



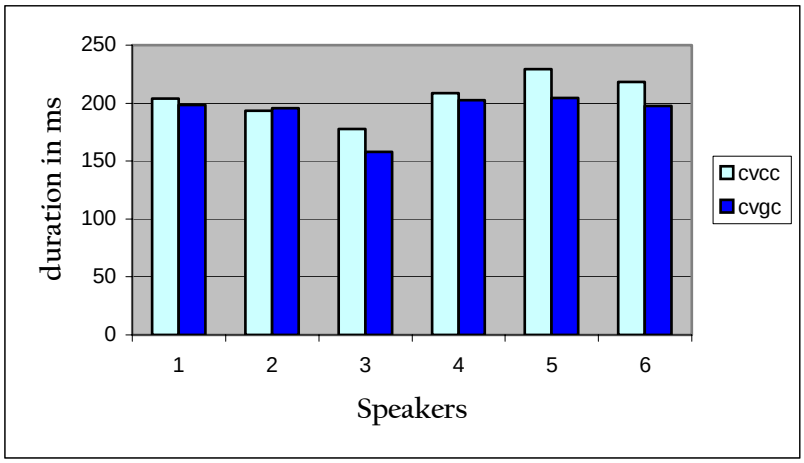
On the other hand, the glottal consonants were not always easy to locate. As a result, I would have to inspect the spectrogram for clues other than visible frication (for /h/) or release (for /ʔ/). For example, in the following spectrogram (Figure 11), the extended period of silence after the vowel seemed too long for one stop. As a result, I included this token in the preserved-glottal cases:

Figure 11: *A token of /boʔd/*



Comparing the vowel durations in the two syllable types, CVCC and CVGC, showed that the stated hypothesis was falsified. The vowel durations in CVCC and CVGC words were significantly different from each other ($t(5)=2.9$, $p<0.04$), with the vowels in CVGC words being shorter than in CVCC words, as seen in Figure 12. This means that when the glottal is absent, we might expect the vowel shortening not to take place, but whether this is a genuine case of compensatory lengthening would require further research.

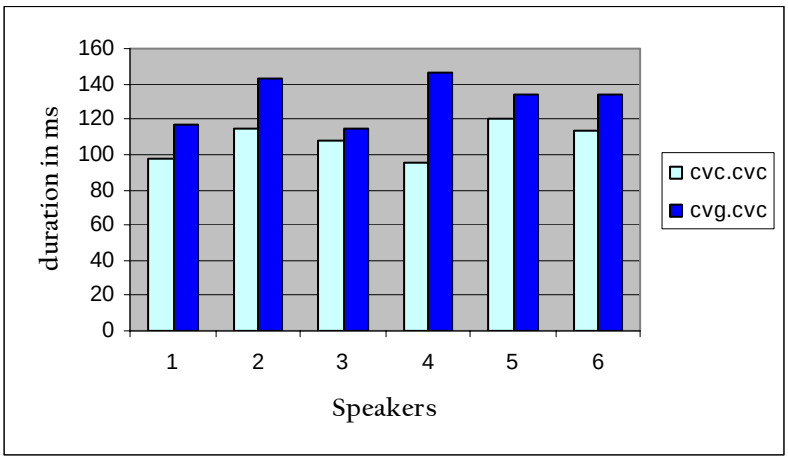
Figure 12: *Mean durations in CVCC and CVGC words*
CVCC:205.25ms, CVGC: 192.75ms (significantly different)



3.3.3. H5: Vowels in CVC.CVC and CVG.CVC words have the same duration

Finally, the duration of vowels were tested in cases in which the glottal is not part of a coda *cluster*. In these cases the duration of the vowels were compared in two cases; when the coda is an oral consonant, and when the coda is a glottal consonant. The hypothesis was that vowels in the first syllable in CVC.CVC and CVG.CVC words have the same duration. This hypothesis was falsified ($t(5)=3.7$, $p<0.02$), suggesting that the two types of consonant, oral and glottal, have different effects on the preceding vowel, as Figure 13 illustrates:

Figure 13: *Mean durations in CVC.CVC and CVG.CVC words*
CVC.CVC: 108.15ms, CVG.CVC: 131.6[5] (significantly different)



[5] This number (131.6ms for CVG.CVC) is slightly different than the number presented in section 3.3.3 where the mean for CVG.CVC was reported as 131.2ms. The reason is that one subject had no tokens in which the glottal was deleted in CVG.CVC words, and was not entered in the paired testing reported in section 3.3.3.

3.4 The correlation between glottal-deletion and compensatory lengthening

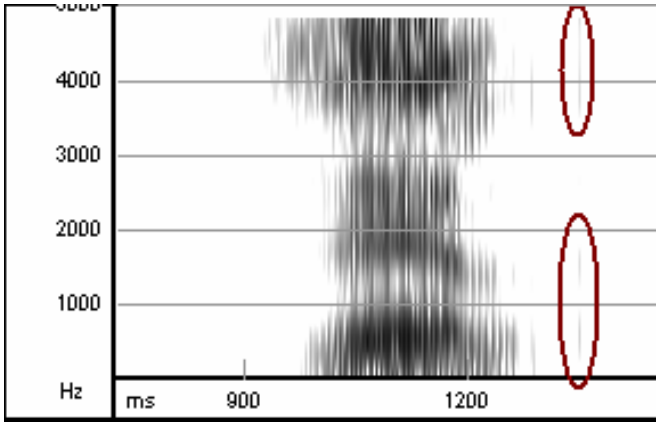
The results of the study, so far, suggest that CVGC cases would be the only cases in which we would expect vowel-lengthening when the glottal is deleted. Nevertheless, all other cases were examined as well. Therefore, the absence of glottal consonants, and its effect on the preceding vowel, in three different positions (CVCG, CVGC, and CVG.CVC) were studied.

3.4.1. Glottal-deletion in CVCG words

The following hypothesis was formulated: "vowels in CVCG words have the same duration, regardless of whether the glottal consonant is deleted." The purpose of this hypothesis was to examine whether the deletion of the glottal had a lengthening effect on the preceding vowel, as predicted by compensatory lengthening. The glottal-deletion was not a common phenomenon among the subjects (21.5% of the time in CVCG words). In addition, since there is glottalization in phrase-final positions in Farsi, sometimes the second token of a word was heavily glottalized, which made it impossible to determine whether the glottal is deleted or not. These cases were eliminated from the analysis.

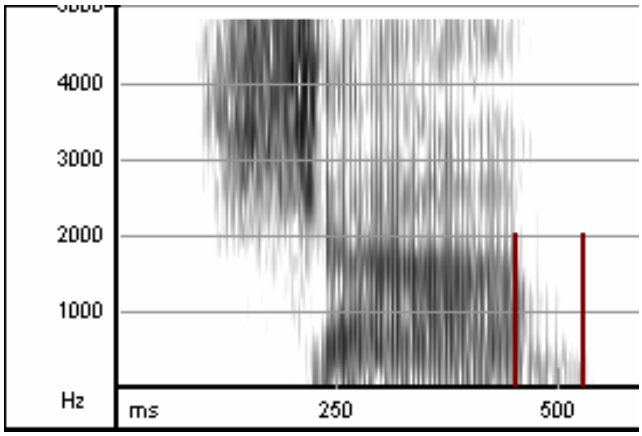
In contrast, there were cases in which the presence of a glottal stop was strongly visible from the release *and* the silent period after the first coda consonant, as in Figure 14,

Figure 14: *A token of /zel?/*



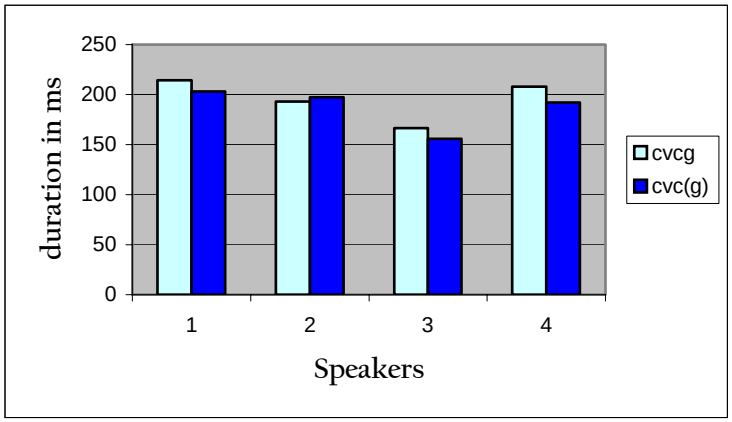
as well as cases in which the glottal segment was clearly deleted with no trace left, as shown in Figure 15:

Figure 15: *A token of /ʃæm?/*



The stated hypothesis was not falsified. The vowel durations in CVCG words with a preserved glottal and CVCG words with a deleted glottal (henceforth represented as CVC(G)) were not significantly different from each other ($t(5)=0.1$, $p>0.1$). Figure 16 shows the mean durations of vowels among subjects who deleted glottals in coda position.

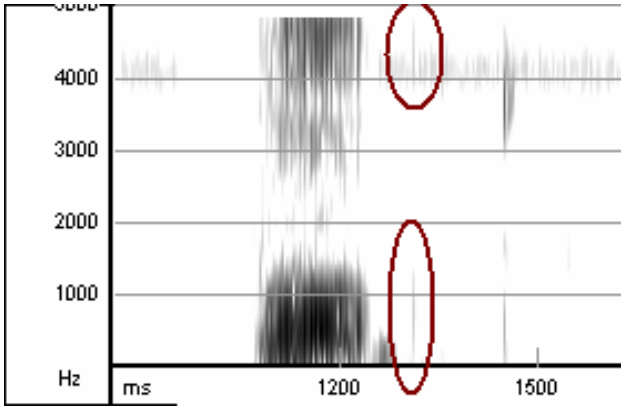
Figure 16: *Mean durations in CVCG and CVC(G) words*[6]
CVCG: 195.6ms, CVC(G): 187.15ms (not significantly different)



3.4.2. Glottal-deletion in CVGC words

The hypothesis, "vowels in CVGC and CV(G)C words have the same durations," was formulated to examine whether the deletion of a glottal consonant in CVGC words has a different effect than in CVCG words.[7] This seems particularly important in the light of the difference observed between CVCG and CVGC cases when the glottal consonant is preserved. As mentioned earlier, in some cases the glottal consonant was clearly visible, as in Figure 17:

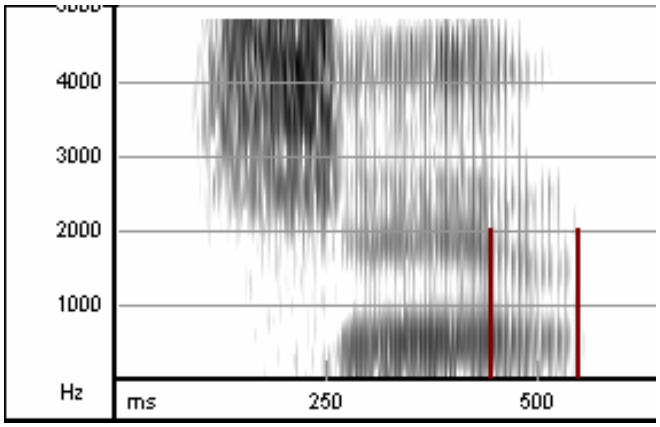
Figure 17: *A token of /boʔd/*



[6] There are only four speakers in this chart because the other two participants did not show any cases of glottal deletion.
[7] Recall that the vowel durations in CVCG and CVC(G) words were not significantly different from each other.

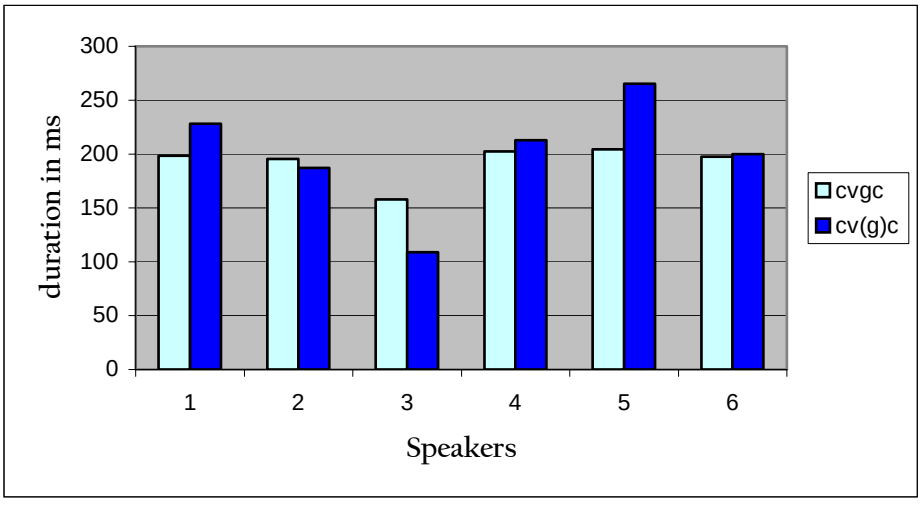
Cases in which the presence of a glottal consonant was not visibly supported were included in the glottal-deleted group, even if slight glottalization was visible on the final segment or the vowel, as in Figure 18:

Figure 18: *A token of /ʃeʔr/*



This hypothesis was not falsified. The vowel durations in CVGC and CV(G)C words were not statistically different from each other ($t(5)=0.5$. $p>0.6$). Furthermore, these word types displayed the least common deletion cases (only 13.5% of the time glottals were deleted in CVGC words). Figure 19 shows the mean durations of vowels among subjects who deleted glottals in coda position.

Figure 19: *Mean durations in CVGC and CV(G)C words*
CVGC: 192.75ms, CV(G)C: 200.4ms (not significantly different)



3.4.3. Glottal-deletion in CVG.CVC words

The hypothesis, "vowels in CVG.CVC and CV(G).CVC words have the same durations," was formulated to determine whether the absence of stress on the vowel preceding the glottal interacts with the presence, or absence, of the lengthening of the vowel. The stress in Farsi is always word-final in monomorphemic words. As a result, the words were chosen with CVG.CV(C)[8] structure, such that all the glottal consonants, both the stop and the fricative, were in an unstressed syllable, in contrast with all the cases discussed so far. Some examples are shown in the Figures 20 – 22.

Figure 20: *A token of /tæʔmiɾ/*

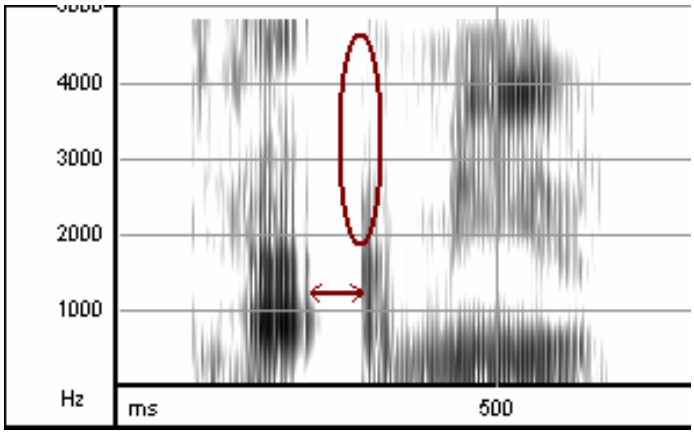
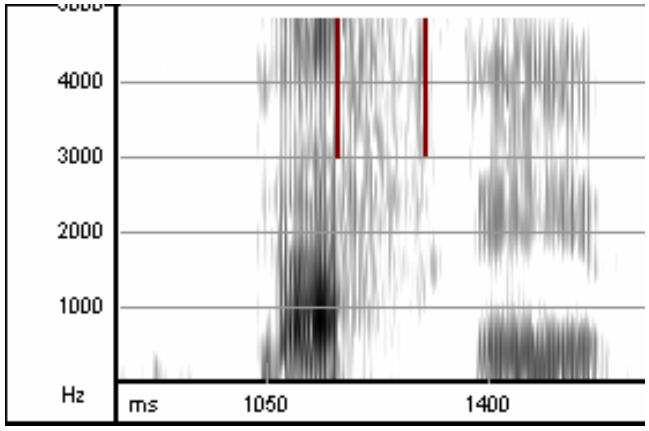
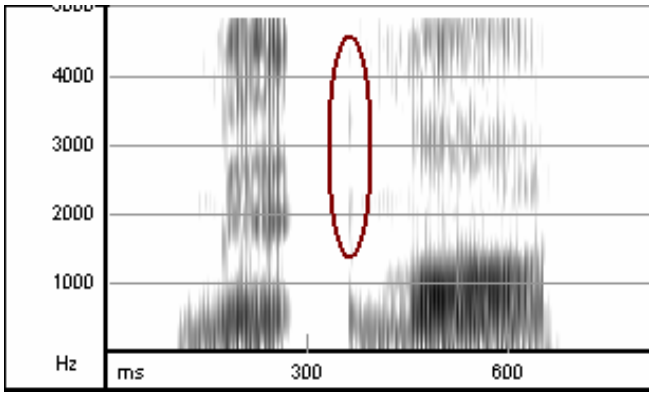


Figure 21: *A token of /tæhqir/*



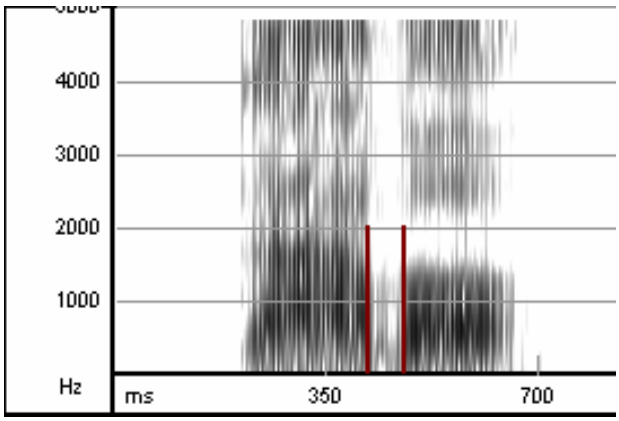
[8] The final syllable was not always a closed syllable (e.g., /toʔme/).

Figure 22: *A token of /meʔmar/*



The following spectrogram in Figure 23 shows an example of a disyllabic word in which the glottal was deleted, and only the fricative, /v/, survives between the two vowels:

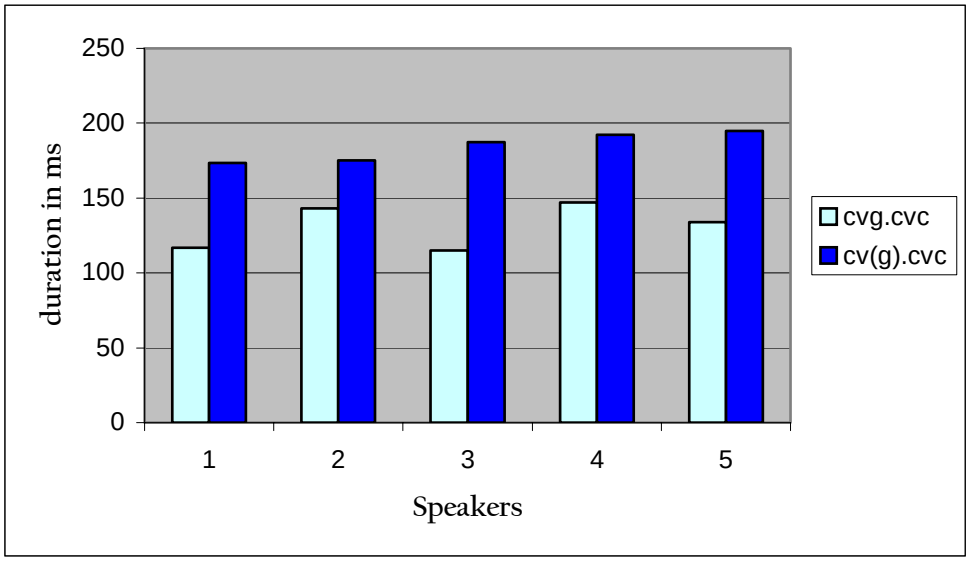
Figure 23: *A token of /dæʔva/*



The stated hypothesis was falsified. The vowel duration in the first syllable of CVG.CVC words was significantly affected by the deletion of the glottal consonant ($t(5)=7.7$, $p<0.002$), such that the glottal-deleted cases showed longer vowels. In addition, in these cases the glottal was more likely to be deleted than in CVCG and CVGC words (23% of the CVG.CVC cases showed deletion). Figure 24 shows the mean duration of vowels in the two contexts.

Figure 24: *Mean durations in CVG.CVC and CV(G).CVC words*

CVG.CVC: 131.2ms, CV(G).CVC: 184.6ms (significantly different)



4. Discussion

Compensatory lengthening in Farsi seems to be more complex than a simple direct relationship between the deletion of a glottal consonant and the lengthening of the preceding vowel. First, the deletion of the glottal consonant does not always result in the lengthening of the vowel. In fact, in some cases the preceding vowel is shorter in the absence of the glottal consonant. The table on the next page summarizes the results of this study:

Table 8: *Significant Results – items compared, results, and comments*

Significant comparisons	CeC vs. CeCC	CeC››CeCC (180.5 ›› 162.5)	/e/ shows pre-cluster shortening
	CaC vs. CaCC	CaCC››CaC (243.4 ›› 201.6)	/a/ shows pre-cluster lengthening
	CvCC vs. CvGC	CvCC››CvGC (505.25 ›› 192.75)	pre-glottal shortening
	CVG.CVC vs. CVC.CVC	CVG.CVC››CVC.CVC (131.6 ›› 108.15)	pre-glottal lengthening (deletion occurs 23% of the time)
	CVG.CVC vs. CV(G).CVC	CV(G).CVC››CVG.CVC (184.6 ›› 131.8)	glottal deletion results in vowel lengthening

Table 9: *Non-significant Results – items compared, and comments*

Not significant comparisons	CvC vs. CvvC (tense vs. lax)	Tense and lax vowels are not significantly different in their durations
	CoC vs. CoCC	/o/ shows no effect of being "pre-cluster" in either direction
	CvCC vs. CvCG	In CvC_1C_2 configuration, C_2 has no effect on the duration of the vowel (occurs 21.25% of the time).
	CvCG vs. CvC(G)	Similarly, C_2 can be deleted without any effect on the vowel's duration
	CvGC vs. Cv(G)C	This is puzzling in the light of the difference observed between CvCC and CvGC, which suggested that the quality of C_1 mattered (occurs 13.6% of the time).

In conclusion, glottal deletion does not seem to be a prevalent phenomenon in Farsi, though it does sometimes occur with its highest occurrence in unstressed syllables. Surprisingly, in stressed syllables, the proximity of the glottal affects the length of the vowel, but its deletion does not. In contrast, cases that do show compensatory lengthening in the face of glottal deletion do not show any pre-cluster shortening. In addition, the differences in the behavior of lax vowels in pre-cluster positions are puzzling to me. While it is possible to speculate that /e/ resists lengthening since it is the shortest vowel and the epenthetic one, it remains mysterious as to why /o/ behaves differently than /a/, which shows pre-cluster lengthening.

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Appendix 1 – Stimuli

1. sedr
2. mesr
3. ketf
4. ʃerk
5. bekr
6. bænd
7. bæzr
8. mærd
9. særd
10. qærz
11. ʃærm
12. moft
13. kord
14. toxm
15. mord
16. felfel
17. kolfæt
18. muʃ
19. kur
20. sut
21. bid
22. sim
23. zir
24. ʃad
25. bal
26. bad
27. ser
28. mes
29. sherover
30. vez
31. bæd
32. bær
33. mæd
34. sæd
35. ʃæmæd
36. tæb
37. tær
38. ʃær
39. bol
40. ʃol
41. bot
42. mod
43. qor
44. meʔmar
45. tæʔbir
46. tæʔmir
47. dæʔva
48. toʔme
49. ʃoʔle
50. tehran
51. behzad
52. bæhre
53. tæhqir
54. mæhmud
55. ʃæhla
56. tohmæt
57. sohbæt
58. tohfe
59. sehr
60. mehr
61. bæhr
62. qæhr
63. mæhd
64. sæhl
65. pæhn
66. ʃæhr
67. bohl
68. fohʃ
69. boht
70. mohr
71. ʃærh
72. tærh
73. mædh
74. solh
75. sobh
76. feʔl
77. ʃeʔr
78. bæʔd
79. tæʔrif
80. qæʔr
81. sæʔdi
82. læʔl
83. boʔd
84. roʔb
85. zelʔ
86. tæbʔ
87. qælʔ
88. ʃærʔ
89. ʃæmʔ
90. xælʔ
91. robʔ