COMPENSATORY LENGHTHENING IN PERSIAN

Vahid Sadeghi

Iran Telecommunication Research Center
Takestan Islamic Azad University
E. mail: va_sadeghi2000@yahoo.com

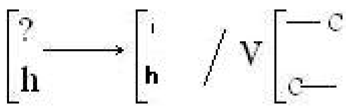
Mahmood Bijankhan
Tehran University, Linguistics Department
E. mail: mbjkhan@ut.ac.ir

ABSTRACT

It is commonly held that Persian glottal consonants in syllable coda undergo vowel lengthening [8], [9]. Some questions have arisen, however, concerning the phonological operations involved in CL. One view suggests that glottal allophonic weakening is compensated by vowel lengthening. Another view holds that CL involves the deletion of a coda glottal consonant followed by the lengthening of the adjacent nucleus vowel. There is a third view which suggests that CL is a gradient process in which different magnitude of glottal gesture is realized in speech from a weak through complete deletion of glottals. Using the spectral tilt measurements H1-H2 and H1-F1, I suggest that CL involves allophonic reduction of glottal gesture, which is accompanied by lengthening of the preceding vowel as glottals attain a gesture much similar to a vowel. In one experiment, subjects colloquially uttered twenty sentences of which ten sentences were made by CVC words and the other ten by CVCC words containing a glottal consonant in coda position. Results of analysis showed that in addition to significant vowel lengthening for colloquial CVCC, the vowel offset H2, H1-H2 and H1-F1 values significantly changed relative to those for CVC data. This suggests that the codaic glottal gesture in CL data is realized in speech with a lax laryngeal setting that causes more length for the preceding vowel.

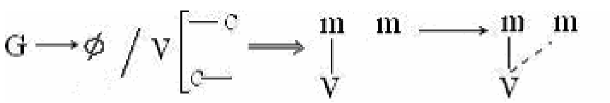
1. INTRODUCTION

There are three competing views concerning the phonological operations involved in CL. The first view maintains that vowel CL occurs as a result of glottal consonant weakening. Thus, /h/ and /?/ in coda change to weak allophones of [H] and ['], as represented below.
This view sees CL as an allophonic weakening of glottal consonants followed by lengthening of the preceding vowel. Samareh [9] asserts that the audition of the weak glottal allophones for Persian speakers is almost impossible, as inferred from the acoustic data.



ˈ and ʰ denote weak allophones of ʔ and h respectively

The second view suggests that CL is triggered by the deletion of glottal consonants. However, there is much argument over the correlation between glottal deletion and CL. Some argue that the deletion of glottals would always result in the lengthening of the preceding vowel, regardless of the adjacency of the glottal consonants and the vowel; hence CVGC, CVCG and CVG.CVC all show CL effect upon the deletion of glottals [3]. This interpretation assumes both moraic and CV phonology, following Hock, to account for CL process. Under this interpretation, glottal consonants delete from the coda and the remaining moras are reassigned to the preceding vowel, as shown below:



G stands for glottals and m for moraic.

Others find deletion-based CL a more restricted process. Shademan [10] maintains that the deletion of glottals does not always result in CL. Her study is based on the logic that if the presence of a coda glottal affects the duration of the preceding vowel, then its deletion should have an opposite effect on the same vowel. Measuring and comparing the duration of vowels in a corpus comprising words of the form CVCC, CVGC, CVCG, CVC.CVC and CVG.CVC, she showed that the adjacency of the glottal to the vowel significantly affected the duration of the preceding vowel. The effect of adjacency, however, was not the same for CVGC and CVG.CVC words. While the presence of G in

CVGC resulted in V shortening, its presence in CVG.CVC triggered V lengthening, suggesting that CVGC data should show CL effect upon the deletion of the glottal, while CVG.CVC data should not. But results showed the opposite effect: CV (G) C data (where parentheses denote deletion) showed no significant CL effect, while CV(G).CVC data did. Upon this finding, she concluded that CL seems to be more complex than a simple direct relationship between the deletion of glottals and lengthening of the vowel. Furthermore, based on the result of her study, she argued that glottal deletion is not a common phenomenon among speakers, suggesting that glottal consonants are more likely to be realized with a weak glottal gesture than to be deleted from coda position.

Both glottal weakening and deletion views predict that vowel structural length is independent of glottal gesture variation in coda position. They differ, however, as to whether it is glottal consonant deletion or weakening that triggers the length.

There is a third view suggesting that Persian CL involves a gradient process in which different magnitude of glottal gesture is realized in speech signal from a weak through complete deletion of glottal consonants. Evidence for this view comes from an experimental study of Persian CL process [1]. In this study, subjects were asked to utter colloquially twenty sentences with embedded CaC and CaCC words. A glottal consonant was present in CaCC, but absent from CaC words. Vowel onset F0, Vowel offset F0, difference of Vowel offset F0 from Vowel onset F0, and vowel duration were computed for CaC and CaCC words using software facilities. Results showed that /a/ onset and offset significantly decreased in parallel with vowel lengthening, suggesting that CL was better to be interpreted as a quantitive variation of glottal gesture in coda position.

The present paper attempts to explore the same question raised in the preceding studies, using spectral tilt measurements. Values of spectral tilt as H1-H2 and H1-F1 were computed for words involving CL (CVCC) and words lacking a glottal gesture in coda position (CVC).Results showed that a significant effect of breathy and creaky voice quality is preserved vowel finally for /h/ and /ʔ/ respectively. This suggests that CL can not be viewed as involving complete deletion of glottals, as predicted by the moraic phonology and the experimental study. Rather, it seems that CL should be interpreted as an allophonic variation of modal phonation through magnitude reduction of glottal gesture. As glottal gesture is not satisfied to reach the intended target, i.e. stop or fricative, through CL process, a laxer laryngeal setting is adopted and glottal consonants arise as allophonic variants of the preceding vowel. Meanwhile, as glottal gesture is reduced, glottal consonants attain vocalic quality which ultimately causes more length for the preceding vowel.

2. CL PHONETIC DATA

Before Providing CL phonetic data, a background of Persian phonology is needed. Persian contains six vowels: /i/, /e/, /a/, /u/, /o/ and /ɑ/, and twenty three consonants of which two are glottal: /h/ and /ʔ/. Syllables are made according to CV(C)(C) template, although some phonologists suggest the optionality of syllable onset due to the predictability of glottal stop in onset position. Main stress falls on the final syllable except for verbs with specific inflectional prefixes.

3. EXPERIMENT

3.1. Subjects and tokens

Twenty native speakers of Persian, with no known history of either phonetics or linguistics served as subjects of the experiment. Two sets of monosyllabic words were selected. Each set contained ten words. The words in the first set, so called Type 1 words, were of the form CVCC, where a glottal consonant appeared in coda position. Of this number, five words contained the glottal fricative /h/ and the other five, the glottal stop /ʔ/. The words in the second set, so called Type 2 words, were CVC counterparts of type 1 words which lacked a glottal gesture in coda position. So, five CVC words were the counterparts of CVʔC, and the other five were the counterparts of CVhC data. The words were embedded in ten sentence frames so that twenty sentences were made with the main stress falling on the embedded words. The subjects were asked to utter colloquially the sentences.

3.2. Recordings

The recordings were made in a sound proof chamber using a Sony cardioid microphone. The microphone was placed at a height equal to and 15 cm in front of the subject's mouth. Digitization was performed at 20 KHz. Separate recordings were made for each of the glottal consonants /ʔ/ and /h/. The data recorded for each included 200 tokens (20 speakers × 2 syllable × templates × 5 words).

3.3. Analysis

Ladefoged [7], following suggestions from Stevens, showed that phonation differences can be quantified through a number of phonetic measurements. Much work on linguistic voice quality has focused on discovering these phonetic dimensions along which contrasts in phonation types are realized [6], [2]. One major phonetic parameter that reliably differentiates phonation types in many languages is spectral tilt [5], i.e. the degree to which intensity drops off as frequency increases. Spectral tilt is known to differentiate phonation types in a number of languages, including Jalpa Mazatec [2] which contrasts breathy, creaky, and modal vowels, !XÓÕ [7], and Gujarati [4] which contrast breathy and modal vowels. It can also differentiate phonation types in languages where nonmodal phonation results from the influence of the neighboring consonants, including Tagalog [2]. Spectral tilt can be quantified by comparing the amplitude of the fundamental to that of higher frequency harmonics, e.g. the second harmonic and the harmonic closest to the first formant [5]. Spectral tilt is most steeply negative for breathy vowels and most steeply positive for creaky vowels [5], [2]. It follows that the increased open quotient and the more gradual glottal closing gesture, which are characteristically associated with breathiness, cause a considerable fall off of energy at higher frequencies, leading to a steeply negative spectral slope [11], while the decreased open quotient and the more precipitous closing gesture which are potentially associated with creakiness cause the least drop off of energy at higher frequencies, though creating some loss at H1, leading to a steeply positive spectral slope [11], [5]. The modal voice occupies the middle ground with its higher frequencies having slightly less amplitude than the fundamental.

It follows that if CL involves the complete deletion of glottal consonants, then the measurements of the changes in the amplitude of the first two harmonics or the first harmonic and the first formant at time near the vowel offset should have similar values for CVC and CVCC tokens. On the other hand, if we assume that CL is triggered by glottal weakening, then the differences H1-H2 and H1-F1 should change substantially near the boundaries relative to the steady state portion of the vowel, and that the spectral tilt values on the end of the vowel in CVCC should be significantly different from those in CVC. Displayed in Figure 1 are FFT spectra of the vowel /a/ sampled at about 15 ms to the vowel offset in the vicinity of the vowel-/h/ (bottom left) and vowel-/ʔ/ (top left) boundary for the words /zahr/ and /baʔd/ by the same speaker. The spectra for /a/ in the CVC counterparts, (/zar/, /bad/) sampled at about the same time, are shown in the right panels. Examination of the data of the kind given in figure 1 indicates that the differences H1-H2 and H1-F1 change substantially near the boundaries. For CVhC data, the differences increase as we approach the vowel offset, leading to a most deeply negative spectral tilt. This increase is a result of a substantial fall in H2. While for CVʔC data, though H1-H2 remains relatively constant, the differences decrease toward the end of the vowel, causing a steeply positive spectral tilt that is due to a fall off in energy at H1. This suggests that what involves in CL is a reduction, rather than deletion, of glottal consonants, followed by lengthening of the preceding vowel.

Figure 1: FFT spectra for the vowel /a/ sampled at 15 ms to the vowel offset. The spectra on the left were obtained in the vicinity of the glottal consonants /ʔ/ (top) and /h/ (bottom) in the words /zahr/ and /baʔd/. The spectra on the right were sampled for /a/ in the absence of a glottal consonant in the words /bad/ (top) and /zar/ (bottom).

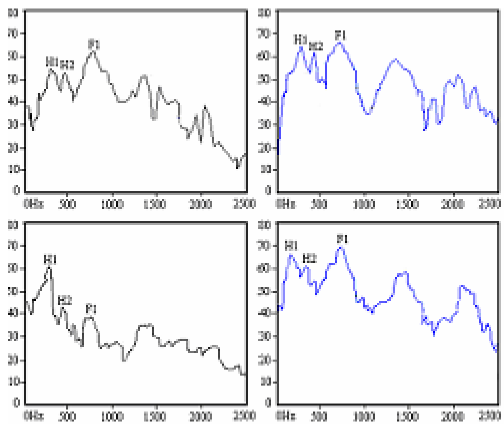
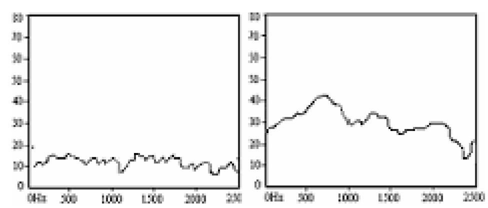


Figure 2: FFT spectra for the [ʔ] (left) and [h] (right) sampled at the steady state portion of the glottals.



Given the clear spectral tilt differences between CVC and CVCC tokens, one might argue that glottals remain simply undeleted in coda position without being laryngealized. However, this cannot be true due to the sharp spectral differences between coda glottals and typical prevocalic glottal consonants. Figure 2 shows the spectra for [ʔ] (left) and [h] (right) in the words / ʔasb/ "horse" and /had/ "limit" respectively. The increased overall acoustic intensity and the small fall off in energy at low frequencies for coda glottals relative to prevocalic glottal consonants indicate that the glottal gesture is indeed weakened in coda, and acquires vocalic attributes through laryngeal vocalization.

Spectra were obtained, for analysis, by calculating a Fast Fourier transform near the vowel offset (about 15 ms to the offset of the vowel). Smoothing was performed using a Hamming window of width about 400 points. Values of phonetic parameters were computed for /V/ vowel of both CVC and CVCC (CVh/ʔC and CVCh/ʔ) words for all subjects using CSL Main Program: (1) H2 amplitude value near vowel offset; (2) H1-H2 amplitude differences near vowel offset; (3) H1-F1 amplitude differences near vowel offset and vowel duration. Four null hypotheses were defined:

(1) Means of H2 vowel offset amplitude for CVC and CVCC words are the same.

(2) Means of H1-H2 difference values for vowel offset in CVC and CVCC words are the same.

3) Means of H1-F1 difference values for vowel offset in CVC and CVCC words are the same.

(4) Means of vowel duration for CVC and CVCC words are the same.

3.4. Result

A Paired-Samples T-test was conducted for each hypothesis. All four hypotheses were rejected with $p<.05$. For hypothesis (1): t[ʔ] (99)= -38 and t[h](99)= -67; For hypothesis (2): t[ʔ] (99)= 21 and t[h] (99)= -31; For hypothesis (3): t[ʔ] (99)= 24 and t[h] (99)= -86, and For hypothesis (4): t[ʔ] (99)= -49 and t[h] (99)= -49. I concluded that in addition to significant vowel lengthening for CVCC, spectral tilt values for /V/ near vowel-/h/ and vowel-/ʔ/ boundaries changed significantly. This indicates that CL results from glottal gesture reduction, rather than deletion, that is accompanied by vowel lengthening. The question is how to theorize this finding within phonological framework.

4. CONCLUSION

A significant finding for CL data acoustic structure was substantial changes in spectral tilt values near the vowel offset, as opposed to non-CL data. To construe the result of the phonetic experiment within phonology, I suggest that coda glottals adopt a laxer laryngeal gesture through CL, resulting in a nonmodal vocalic gesture that causes more length for the preceding vowel. So, contrary to both moraic and allophonic weakening theories that assume vowel lengthening as an independent operation following deletion and weakening, I suggest that vowel length is dependent to the laryngeal variation of glottal consonants in coda position. In addition, given that glottal consonants are orally unmarked and dependent on the preceding vowel, it is not surprising that CL applies irrespective of whether glottals are in the first or second position of the coda. Meanwhile vowel length and spectral tilt values are phonetically significant acoustic cues that can be used to identify CL words from non-CL words. Hence, the result of this study can be used to improve ASR.

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