Laryngographic, Acoustic and Perceptive Study of Glottalization Phenomena in Persian

Sh. S. ASSADI
Laboratoire de Phonétique et Phonologie (UMR 7018) CNRS / Sorbonne Nouvelle, Paris, France
E-mail: assadi@msh-paris.fr

ABSTRACT

Glottalization phenomena in the literary Persian of Tehran is shown to assume three different functions: (i) a prosodic function, (ii) a segmentally distinctive function, and (iii) a final creak. What have the three types of glottalization phonetically in common? Laryngographical and acoustic results indicate that the irregular vibration of the vocal folds and the decrease in F0 are the most frequent correlates of the three glottalization types. The irregularity for the three cases is essentially of the creaky voice type, as described by Fourcin, 1981 and Ladefoged, 1996. Speech rate has various effects on the first two types, but no effect on the final creak. Word initial vowels start in most cases with at least two irregular vibrations, but do not necessarily begin with a complete glottal closure, unlike what is indicated in the literature.

1. INTRODUCTION

Glottalization exists in many languages such as English,German, Arabic, Hebrew, Danish, Persian, Vietnamese, Chinese (associated with a low tone), African, Indonesian, and American Indian languages, etc. Glottalization is a vague term and it is related to the notions of creak, creaky voice, laryngealization, glottal stop, the articulation of ejectives and implosives [10]. The glottalization phenomena can assume different functions such as: i) marking a word or morpheme boundary beginning with a vowel, ii) being identified as a phoneme, iii) replacing sometimes the articulation of a plosive and iv) changing the quality of voice at the end of a declarative sentence and in low tones, etc.

2. Glottalization Phenomena in Persian

There are few articles on the glottalization in Persian, and almost none on its physiological aspects. The goal of this research is to explore glottalization phenomena in Persian acoustically, physiologically and perceptually, and to take under consideration if glottalization phenomena behave differently with respect to speech rate.
The research corpus included isolated words, isolated sentences and texts. Glottalization will be studied in three positions :

1. Glottal stop in initial position in a word starting with a vowel, as a boundary signal.
2. Glottal stop in middle and final positions in Arabic loanwords, as a phoneme (well-studied by phonologists).
3. Final creak, at the end of a declarative sentence (never mentioned in the literature for Persian).

The present research is intended to provide answers to the following questions:
- Do all the word initial vowels begin with a glottal stop?
- Does the initial glottal stop play a role in the perception of the word as indicated in the Persian literature?
- Is the glottal stop realized by a complete glottal closure in the middle and end of Arabic loanwords?
- What are the common acoustic manifestations of the glottalization phenomena in Persian?
- Does speech rate influence glottalization phenomena?
- From the physiological point of view, do glottal cycles always correspond to acoustic ones?

2 .1. Method

2.1.1. Acoustic analysis

220 isolated words with phonological « glottal stop» in initial, middle and final positions were recorded from two female native speakers from Tehran and analysed.
A word in isolation being also a prosodic sentence, the word initial and final positions correspond to the sentence initial and final positions [Vaissière; personal comunication].
Each word was presented to the speaker on a separate card, with an interval of three to five seconds.
In this study, the term «glottalization» is used to describe the irregular vibrations of the vocal folds and «glottal stop» is referring to a silence following an «explosion». The signals of the two types are illustrated in Fig. 1 and 3.

2.1.1.1. Glottal stops in initial position

The duration of the irregular period at the beginning of the vowel has been measured.
Results show that:
- 37% of the vowels in the initial position start with a glottal stop, followed by irregular vibrations, and 63% with 2 to 8 irregular vibrations without a complete closure.
- The irregularity can be in the duration, shape and/or amplitude of the period. It is larger at the beginning of the vowel then it decreases and ceases after about 30 milliseconds from the beginning for one subject and 20

 ISBN 1-876346-48-5 © 2003 UAB

milliseconds for the other (mean of 25 ms for the two speakers). 25 ms seems very short compared to the glottalization in German whose duration rises to 64.1 ms in a corpus of texts and spontaneous speech [2].

2.1.1.2. Glottal stops in middle and final positions

- There are more variations in middle position than at the beginning of the word. There is a complete closure in 25% of the cases especially in the case of gemination of /ʔ/, and /ʁ/ at the beginning of the syllable. There is glottalization in 67% of the words and 8% contain the deletion of /ʁ/ with a compensatory lengthening of the previous vowel.

- In final position, 80% of the /ʁ/ are deleted, with a compensatory lengthening of the previous vowel. A complete glottal closure occurs in 10%, with the insertion of an epenthetic [e] after /ʔ/. In 10%, there is glottalization.

(A discussion about initial, middle and final positions is held in [1]).

2.2. Perceptive analysis

According to [11] if the initial /ʔ/ were omitted from the beginning of a word, the rest of the word would not make any sense. Our perceptive analysis aims to verify this assumption. 14 items were selected for analysis (7 words, 2 native Persian speakers, the same as for the acoustical analysis). The mean duration of the glottalization portion at the beginning of the vowel was respectively 21 and 32 ms for the two subjects. It was cut off, thus creating a hard start of the vowel. Ten Persians (aged from 18 to 35) heard three to five times every unmodified and corresponding modified versions of the 14 stimuli through earphones. The following question was written:

-Do you perceive the same words in each pair?

None of the listeners perceived any difference between the words with and without the first irregular vibration. It seems that a hard start is perceptually equivalent to glottalization at the beginning of the vowel. So, this can not change the meaning of the word, as indicated by [11]

2.3. Laryngographical analysis

A laryngographical analysis was performed for only one speaker. For the other, it was not possible to obtain reliable data. As mentioned [3] (p : 251): “The EGG signal was not always obtainable from patients, especially from some women and patients with thick necks.”

In this analysis, we studied :

1. Isolated words (the same words as in acoustic analysis).
2. Isolated sentences: 18 sentences (with the same vowels on the word, morphem and syllable boundaries)

Results

2.3.1. Isolated words

-In initial position, Lx (laryngographical signal) shows an approximation of the vocal folds before the beginning of the vowel. The vowel starts with an open glottis. Figure 1 shows typical glottal stop and glottalization of the initial vowel.

- In middle position, there are many variations for /ʔ/. The glottal stop can be realized by complete glottal closure + glottalization. So, in 14% of the cases, the acoustic signal shows a brief silence (< 30ms).

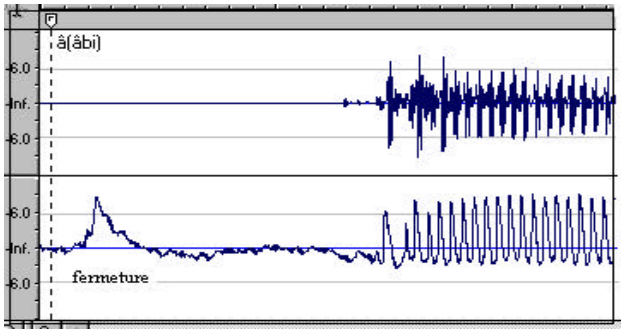

Figure 1: the initial vowel of the word [ʔâbi] (blue). Acoustic signal at the top and Lx at the bottom.

Consequently, there is no intensity for a very short duration. Lx shows a long closure phase (Figure 2).

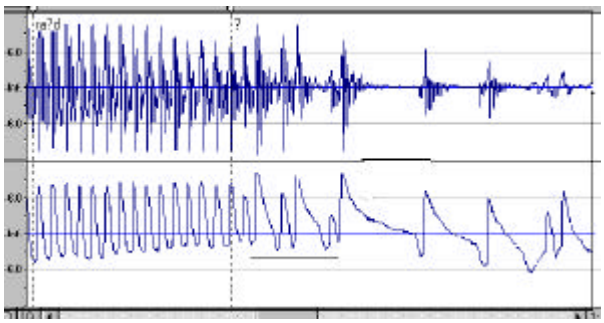

Figure 2:glottal stop in the middle of the word [raʔd] “thunder”. Acoustic signal at the top and Lx at the bottom.

In 10% of the cases, the silence is more than 40ms and one observes a correspondence between the duration of the silence on the acoustic signal and the return to the baseline of Lx. In 64% of the cases, the irregularity is in frequency (and amplitude) (figure 3). In 10% of the cases, /ʔ/ is deleted. 2% of the cases are ambiguous.

- In a word final position, a complete closure occurs when [ʔ] is pronounced by insertion of an epenthetic [e] after /ʔ/.

2.3.2. Isolated sentences

In modal voice, the acoustic cycle corresponds to the glottal one. In case of glottalization, there is either the doubling of the period [6] [9]. In this case figure 2 shows that one glottal cycle corresponds to two acoustic ones or there is a correspondence between the acoustic and glottal cycles with irregularity in the amplitude (figure 3).

ISBN 1-876346-48-5 © 2003 UAB

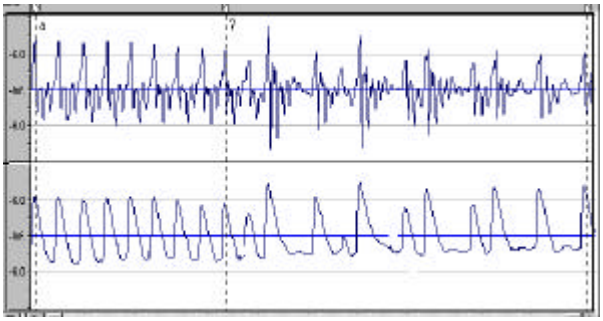

Figure 3 :glottal stop in the middle of the word [baʔd] "after". Acoustic signal at the top and Lx at the bottom.

This can be due that « ligamental and arytenoid parts vibrate separately, so that they are out of phase with one another » [9]. One observes many variations in signals that show the dynamic of the production system

Final creak: Figure 4 illustrates the irregularity in amplitude, frequency and duration of the Lx and acoustic signal.

A fast transition to the low frequencies is a common correlate in all glottalization types.

3.The effect of speech rate

The effect of speech rate on glottalization phenomena was studied in texts read by the two subjects. 228 words with « glottal stop» in initial, middle and final positions were analyzed. An ordering of different possible realizations of glottal stop has been done [7] in slow rate:

- ʔ1 :« glottal closure »+ glottalization (Figure 1)
- ʔ2 :« glottal closure»
- ʔ3+ :glottalization (Figure 3)
- ʔ3- :Amplitude decreased.

Each word was compared to its correspondent at a fast rate.

Results

Speech rate has different effects according to the glottal stop position:

-in initial position, Chi 2 test shows that speech rate affects significantly the strong form of glottal stop (complete closure) $p<0,0001$. It means that «Complete closure + glottalization » in slow rate becomes glottalization in fast rate (a weakened version of glottal stop). The glottal closure is a reinforcement of glottalization [8] [5]. The difference is due to different degrees of medial vocal fold compression [5].

In both speech rates, the glottalization is the most frequent realization of the glottal stop.

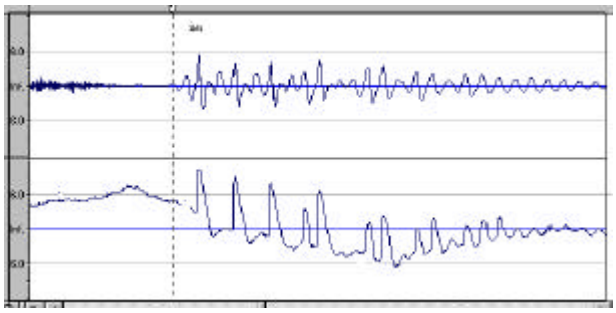

Figure 4 : Final creak at the end of the sentence in the word : […minuʃim] "we drink…." Acoustic signal at the top and Lx at the bottom.

-In middle position, fast rate resultes in a significant deletion of /ʔ/ (10% in slow rate as opposed to 43% in the fast rate; $p<0,0001$). The deletion can be accompanied by the compensatory lengthening of the previous vowel.

- In final position, a deletion of /ʔ/ is generally observed in both speech rates.
- Final creak: our observations show that the end of a declarative sentence with decreasing F0 and intensity can be accompanied by a creak in Persian. Speech rate doesn't have any effect on the final creak.

4. Conclusion

Acoustic and physiological studies provide complementary information about the state of the glottis. Some of it such as the variability of the glottal closure and period doubling etc. are clearer in Lx than acoustic signal. This study showed that irregularity is a common cue to glottalization contexts and seems to be universal although it can be manifested in different forms. There are large inter-speaker variations [4], which makes the study of glottalization phenomena difficult. However, we found a scale of reinforcement from glottal stop, through glottalization, to decrease in amplitude, which was common to the two speakers. It is necessary to examine the glottalization phenomena for more subjects and to find whether glottalization can be a factor which contributes to the identification of the speakers and how far each speaker is consistent with his/her choice.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Prof. Vaissière, Prof. Asadi, Dr. Fourcin and J.P. Ricot for their guidance comments.

ISBN 1-876346-48-5 © 2003 UAB

REFERENCES

[1] Assadi Sh. S. « *Les phénomènes de glottalisation et de réduction en persan*.» Thèse de doctorat. Université de la Sorbonne Nouvelle. Paris, 2003.

[2] Batliner A., Burger S., Johne B. and Kiess1ing A. « Müsli: A classification scheme for laryngealizations ». In *Proceedings of the ESCA workshop on prosody Working Papers* 41, pp : 176-179, 1993.

[3] Behrman A. and Agresti C. J. « Microphone and electroglottographic data from dysphonic patient : type 1, 2, and 3 signals ». *Journal of Voice.* Volume, 12, No. 2, pp. 249-260, 1998.

[4] Dilley L. and Shattuck-Hufnagel S. « Variability in glottalization of word onset vowels in American English ». *Proceedings of the XIIIth international congress of phonetic sciences.* Stockholm. Vol. 4. pp : 586-589, 1995.

[5] Fischer-Jorgensen, E. « Phonetic analysis of the stod in Standard Danish ». *Phonetica* 46, pp. 1 –59, 1989.

[6] Fourcin A. J. « Laryngographic assessment of phonatory function ». *The American Speech – language - Hearing Association.* Rep.11, pp. 116-124. 1981.

[7] Kohler K. J. « Glottal stops and glottalization in German ». Data and theory of connected speech processes. *Phonetica* 51, pp. 38 – 51, 1994.

[8] Kohler, K.J. « Glottalization across languages». *AIPUK 30*, pp. 207-210. Kiel, 1996.

[9] Ladefoged, P. and Maddieson, I. *The Sounds of the World's Linguages*. Blackwell Publishers. Oxford, Cambridge . 1996.

[10] Ladefoged. P. *Preliminaries to Linguistic Phonetics*, University of Chicago Press, 1971.

[11] Samare Y. *The arrangement of segmental phonems in Farsi*. University of Tehran. Iran 1977.

ISBN 1-876346-48-5 © 2003 UAB