WHY DO GLOTTAL STOPS AND LOW VOWELS LIKE EACH OTHER?

Jana Brunner & Marzena Żygis

Centre for General Linguistics, Berlin, Germany
brunner@zas.gwz-berlin.de; zygis@zas.gwz-berlin.de

ABSTRACT

The aim of the present study is two-fold. First, we will show that glottal stops/glottalization and low vowels are likely to co-occur in typologically different languages. Second, we will investigate the question whether this widely attested co-occurrence of glottalization and low vowels could be due to a perceptual phenomenon; i.e. differences in the perception of vowel quality of glottalized as compared to non-glottalized vowels. We hypothesized that vowels are perceived lower in their height if they are glottalized. In order to test our hypothesis we conducted a perceptual experiment with two German continua of *b[i]ten-b[e]ten* ('to offer', 'to pray'), a non-glottalized and a glottalized one. 23 German subjects took part in an identification test in which they were asked to indicate whether they perceived words from these continua as *b[i]ten* or *b[e]ten*. The data show very clearly that subjects perceive *b[e]ten* more often than *b[i]ten* if the vowel is glottalized. This result indicates that the co-occurrence of glottal sounds and low vowels in the languages of the world could actually originate in a reinterpretation of glottalized higher vowels as lower ones.

Keywords: glottal stop, glottalization, vowel lowering, perception, sound change

1. INTRODUCTION

An investigation of phonological phenomena involving glottal stops and vowels shows that the presence of glottal stops/glottalization influences the quality of the surrounding vowels: the vowels are lowered. Such processes take place in several typologically different languages. Other types of evidence including orthography and phonotactics also point to a preference of low vowels rather than non-low ones to co-occur with glottal stops/glottalization.

1.1. Phonological processes

In Klallam (a Salish language), the non-low vowels /i u ə/ are lowered to /ɛ o a/, respectively, when followed by [ʔ]. For example, /pʔ ɬ́ kʷŋ/ is pronounced as [pʔɛʔxʷŋ] 'overflow'/'overflowing' and /š úpt/ as [š óʔpt] 'whistle'/'whistling' [17].

In the reduplication processes in Nisgha (a Tsimshianic language) the quality of the vowel in the prefix depends on the surrounding segments. If the stem starts with a coronal stop, the vowel in the prefix is also coronal: /tamʔ/ is reduplicated to [tim-tamʔ] 'to press' but if the initial-stem consonant is a glottal stop the vowel in the prefix is the low vowel [a]: /ʔux/ is pronounced as [ʔax-ʔux] 'to throw' ([14], [15]).

In Tigrinya (Ethio-Semitic language), the mid central vowel /ə/ is lowered to [a] following pharyngeals and laryngeals in the regular conjunction pattern. For example, /səbərə/ is pronounced as [ʔabərə] 'he broke/he arrested' ([1]).

Lillooet (a Salish language) shows a clear coarticulation induced variation in schwa-epenthesis: [ə] changes to [ʊ] in between labialized non-uvular/non-pharyngeal consonants ($C^w\_C^w$), to [ɔ] before labialised uvular/pharyngeal sounds, and to [ɪ] between coronal sounds. However, if a glottal stop follows the schwa, then the schwa changes to [a] ([14], [16]).

In Besleney (an East Circassian language) the epenthetic schwa [ə] is realized as [i] in the context of palatalized consonants, as [u] in the environment of labialized consonants and as [a] near gutturals including laryngeals ([11], [14]).

In Karanga and Zezuru (dialects of Shona, a Bantu language) the hiatus, i.e. the co-occurrence of two adjacent vowels is resolved in the following way: if the second vowel is /i/ or /e/ a glide [j] is inserted between the vowels. If the second vowel is /u/ or /o/ a glide [w] is inserted. However, if the second vowel is /a/, then the glottal stop appears ([9]).

1.2. Other types of evidence

Besides phonological processes there are also other types of evidence suggesting that low vowels are likely to occur with glottal stops/glottalization. One piece of evidence comes from voice quality which shows preferences regarding the quality of the vowel. For example, in the Mon-Khmer register a breathy voice quality corresponds to a raised vowel but a tense voice quality corresponds to a lowered vowel ([4]).

Even orthography provides evidence regarding the co-occurrence of glottal stops and low vowels. In Amharic some stems have an initial /a/ which is interpreted as a historical remnant of a lost laryngeal (or pharyngeal) stem-initial consonant, cf. ([6]).

There are also phonotactic restrictions concerning glottal stops and vowels. For example, in Kiribati (an Austronesian language), a glide /w/ occurs in the context of the following /i, e/ (C_i, e), whereas a glottal stop is found only in the context of a following /a/ (C_a) ([5]).

Finally, a crucial piece of evidence comes from an investigation of German spontaneous speech, cf. [13]. It has been shown that the word-initial low vowel /a/ is significantly more often glottalized or preceded by a glottal stop than a word-initial mid or high vowel. This holds for the four different speech rates investigated in this study.

1.3. Hypothesis

Previous studies show that there is a cross-linguistic tendency for low vowels and glottalization to co-occur. The consistency with which this co-occurrence can be found in the most diverse languages leads to the assumption that it might be the result of a very general property of human articulatory and/or perceptual capacities. In fact, we believe that the perceptual effects of the phenomena we are discussing are consequences of preferable laryngeal settings, especially a retracted tongue root and higher larynx (often due to a sphincter mechanism), a point which we, however, will be not discussing in this paper.

In the present study we investigate the question whether the co-occurrence of glottalization and low vowels could be due to a perceptual phenomenon, i.e. differences in the perception of vowel quality of glottalized as compared to non-glottalized vowels. More specifically, if glottalized vowels are perceived lower in their quality then the observed co-occurrence could be a result of a perceptual reinterpretation of glottalized vowels as vowels with a lower vowel quality, e.g. a glottalized [i] is perceived as [e] (cf. [10] for a listener as a source of a sound change (cf. [10] for a listener as a source of a sound change).

If glottalized vowels are generally perceived as having a lower quality this should also be true for high vowels. The aim of the present study is therefore to investigate the perception of vowel quality of high glottalized and non-glottalized vowels.

2. METHODS

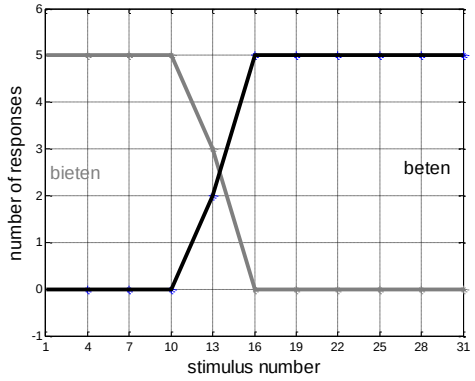
A trained male native German speaker was recorded speaking the words b[i]ten <bieten> (‘to offer’) and b[e]ten <beten> (‘to pray’) without glottalization. Variants of the words which differed in the stressed vowel only were created by splicing the vowel [e] from *beten* into the *bieten*-utterance. The words were afterwards made exactly the same length by stretching the shorter one. The f0 contours were equalized as well. Glottalized variants of these manipulated utterances of *bieten* and *beten* were created by lowering f0 of [i] and [e] to 50Hz over the complete vowel duration. Glottalization is characterized by a low f0, reduced amplitude and a flattened spectrum ([3]). It has been shown, however, that f0-reduction is sufficient for the perception of glottalization ([12]). The manipulation was done in the software PRAAT ([2]). It resulted in perception of a creaky vowel. Then two continua with 31 steps were created, one from the non-glottalized variants of the two words and one from the glottalized variants by interpolating between the two speech samples in 30 equal steps ([8]).

A forced choice identification test, consisting of two parts, was set up to test whether listeners perceive the boundary between [i] and [e] more towards [i] on the glottalized continuum than on the non-glottalized continuum. A forced choice test was used rather than an AX-test because the AX-test has been shown to be prone to response biases ([7]). The phonemic boundary tends to be hearer-specific. In order not to have to test all the samples from the complete continuum, we decided to first locate the approximate boundary by testing only every third stimulus on the non-glottalized continuum. This first part of the experiment consisted of five blocks (i.e. each stimulus was presented five times). The stimuli were randomized in each block. For each hearer the sample where perception switched from *bieten* to

beten (i.e. where the *beten*-responses first outnumbered the *bieten*-responses) was determined. This sample will be called *post-crossover sample*. If there was more than one crossover point, a mean over the first and the last post-crossover sample was calculated.

Figure 1 shows the result of this pre-test for one subject. The stimulus numbers of the continuum are given on the abscissa. Stimulus 1 is the *bieten*-anchor and stimulus 31 is the *beten*-anchor. The subject classified all five repetitions of stimuli 1, 4, 7 and 10 as *bieten* (grey line), but only three of the five repetitions of stimulus 13 and none of the remaining stimuli. The post-crossover sample is thus sample 16 for this speaker, although it might be different for other speakers.

Figure 1: Result of the pre-test for determining the approximate location of the boundary between /i/ and /e/ for one subject. Grey: number of *bieten*-responses per stimulus. Black: number of *beten*-responses per stimulus.

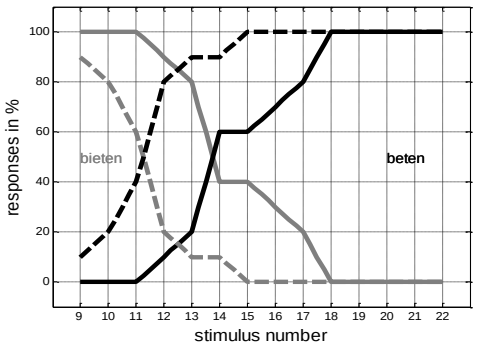


In the second part (the main experiment) perception around the post-crossover sample was tested by presenting stimuli from both continua in the range post-crossover sample-7 samples and the post-crossover sample+6 samples. In this second 10-block experiment glottalized and non-glottalized variants were presented in randomized order. Figure 2 shows the data for the same subject as in Figure 1. The solid lines show the results for the non-glottalized stimuli, the dashed ones show the results for the glottalized stimuli.

The classification is now less clear than in the pre-test since in the main experiment stimuli around the crossover were tested. The post-crossover sample for the non-glottalized continuum is now 14, for the glottalized it is 12.

A generalized linear mixed model was calculated with *response* (*bieten* or *beten*) as the dependent variable, *glottalization* (glottalized or non-glottalized) and *sample* (on the continuum) as fixed effects and *subject* and *repetition* as random effects. 23 German native informants (5 males, 18 females) aged between 18 and 29 took part in the experiment.

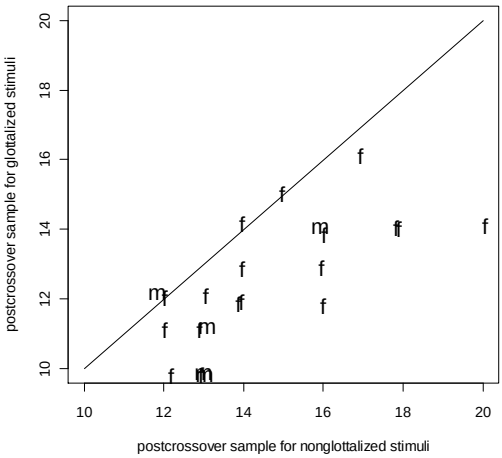
Figure 2: Result of the main experiment for the same subject as in figure 1. Grey: *bieten*-responses. Black: *beten*-responses, solid: non-glottalized stimuli, dashed: glottalized stimuli.



3. RESULTS

Figure 3 shows the distribution of the post-crossover samples for the non-glottalized (abscissa) and glottalized continuum (ordinate) for all subjects. Letters 'm' and 'f' represent male and female subjects, respectively.

Figure 3: Post-crossover sample for the non-glottalized (abscissa) vs. the glottalized continuum (ordinate) for all subjects. 'm': male subject, 'f': female subject. Some noise was added in order to make all data points visible.

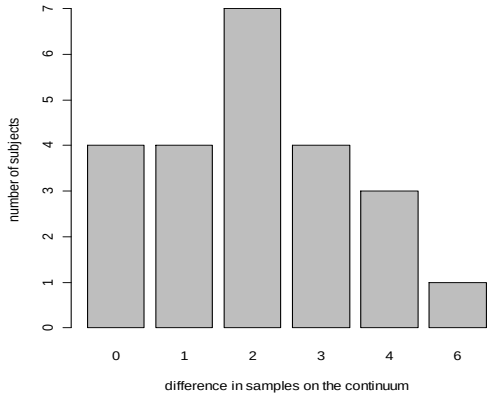


If all the subjects had the same post-crossover sample both for the non-glottalized and the glottalized continuum they should all be on the diagonal line. However, most data points are below the line indicating that the subjects' post-crossover sample is more towards the *beten* end of the continuum for the non-glottalized variants than for

the glottalized variants. The subjects thus perceive more often *beten* if the vowel was glottalized than if it was not.

Figure 4 summarizes a detail of what can be seen in Figure 3; i.e. how far apart the post-crossover samples for the non-glottalized and the glottalized continua were for different subjects. On the horizontal axis the difference in steps can be found, on the vertical axis the number of subjects with a certain distance is given. There are four subjects who did not hear the stimuli differently (difference=0). All the others switched between 1 and 6 steps earlier from *bieten* to *beten* on the glottalized than on the non-glottalized continuum.

Figure 4: Differences in post-crossover samples between the glottalized and the non-glottalized stimuli for all subjects.



A generalized linear mixed effects model for the data shows that there is a highly significant effect for *sample on the continuum* and *glottalization* (for both p<.001).

4. CONCLUSIONS

A typological investigation of different phonological processes (reduplication, epenthesis, vowel lowering) reveals an influence of glottal stops/glottalization on the quality of the surrounding vowels. It appears that glottal sounds systematically co-occur with low vowels.

The aim of the present experiment was to test whether this cross-linguistic tendency could be perceptually driven. The results of the perception experiment we conducted on high vowels with 23 informants are in line with our hypothesis: vowels are perceived lowered in their quality if they are glottalized.

The co-occurrence of low vowels and glottal stops/glottalization could therefore be due to a reinterpretation of higher glottalized vowels as lower in their perceived height.

5. ACKNOWLEDGMENTS

This study was supported by the German Federal Ministry for Education and Research (grant 01UG0711). We would like to thank Phil Hoole for a program for carrying out the perception tests and to Holger Mitterer for a script for creating continua.

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