LARYNGEAL ADJUSTMENTS IN THE PRODUCTION OF VOICELESS OBSTRUENT CLUSTERS IN BERBER

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ABSTRACT: Laryngeal adjustment in voiceless obstruent clusters was examined by means of simultaneous transillumination, fiberoptic films and acoustic recordings. Haha Tashlhiyt Berber was studied since this language allows a rich variety of voiceless clusters naturally. Several combinations of /s/ and /k/ clusters including singleton consonants as well as geminates were taken into account. We focus on the number of glottal opening peaks, the influence of manner of articulation and effects of word boundaries. Results of this preliminary study provide evidence that the manner of articulation of segments and their position in the clusters have a major impact on the number of glottal opening peaks, whereas word boundaries did not influence laryngeal adjustment to the same extent. We conclude that aerodynamic requirements play a major role in laryngeal coarticulation.

INTRODUCTION

A number of studies have investigated laryngeal articulation, in particular gestural aggregation, during the production of voiceless consonant clusters. Pétursson (1977), Fukui & Hirose (1983) and Jessen (1999), for example, have observed glottal adjustment and the number of glottal opening peaks in fricative-stop clusters. In Pétursson (1977), [-s#t^h-] and [-s+t^h-] clusters show two glottal opening peaks whereas only one peak occurs in /st-/. The author concludes that there are discrete phoneme commands for glottal abduction although the intervening word boundary might have influenced the pattern too. In Fukui & Hirose (1983), the two-peakedness in [s#p^h] clusters was rather speaker-dependent. One explanation of these differences could be that two different glottal abduction gesture underlie, and in a fast speech rate condition, they overlap whereas no overlap would be found in a slow speech rate condition. Munhall & Löfqvist (1992) investigated this issue in [-s#t^h-] clusters and simulated gestural overlap as a sum of the two underlying movements. Their simulations fit the transillumination data with respect to timing characteristics, but differences are found concerning glottal opening amplitudes. The simulations showed higher amplitudes than the experimental data: They explain these differences in terms of the non-calibration possibility of the transillumination technique as well as in terms of rate effects, which can decrease movement amplitudes. Jessen (1999) raised the question whether the mono-modal versus bi-modal distribution of glottal opening movements would be an effect of the word boundary or whether aspiration of the stop in the fricative-stop cluster could explain the distinction. His findings confirm the latter idea. This idea is based on results from Löfqvist and Yoshioka (1980), and Yoshhioka et al. (1981) on Swedish and English. They indicate that glottal opening is characterized by one-, two or three-peaked pattern according to the nature of the voiceless obstruents and the way they are combined. Each voiceless obstruent or geminate accompanied by aspiration or frication noise tends to require a single separate peak of glottal opening. These independent glottal apertures are interpreted as assuring the aerodynamic requirements for turbulent noise production during the aspirated stop or fricative segment.

Berber is a language spoken in North Africa. Haha Tashlhiyt Berber (Henceforth HTB) is spoken in the Southern part of Morocco. HTB uses both voicing and gemination distinctively. Both singleton and geminate velar and dental stops may be aspirated in pre-vocalic position. Following a commonly accepted view, we consider geminates a single melodic units associated with two prosodic positions. Such a representation accounts for the dual behavior of the geminate which behaves in some respects as a consonant cluster and, in others, as a single consonant. Heteromorphemic geminates are a sequence of two identical segments separated by a morpheme boundary. They are generally

homophonous with tautomorphemic geminates. In certain contexts, however, as is the case with /k#k/, the first velar stop may either be released or spirantized. Spirantization is an optional phonological process affecting simple noncoronal stops. HTB is of special interest for improving our understanding of the organization of laryngeal gestures, since his language allows an unusual rich combination of voiceless sounds, different types of geminates, heteromorphemic and tautomorphemic, in initial, medial and final positions (Ridouane, 2001). In this preliminary study we will focus on the following topics:

1. the number of glottal opening peaks during different clusters;

2. the influence of manner of articulation or of gemination on glottal adjustments;

3. the effect of preceding, following or intervening word boundaries.

Our data could give additional evidence for the interpretation that a static glottal opening position of the glottis is unlikely to occur (e.g. Yoshioka. Löfqvist & Hirose 1981, Munhall & Löfqvist 1992), since we included voiceless /s/ and /k/ combinations up to 5 consonants in our data.

METHOD

In order to investigate laryngeal adjustment in consonant clusters one male native speaker of HTB was recorded by means of simultaneous transillumination (hereafter PGG), fiberoptic filming (hereafter FF), and acoustic recordings. A standard endoscope of the type Olympus ENF (type P3) was inserted in the subjects pharynx and a photosensor was glued externally on the subjects neck below the cricoid cartilage. The endoscope was attached to a camera and connected to a video recorder with a monitor. The video images enabled the otorhinolaryngologist to control the position of the tip of the endoscope throughout the experiment. The video signals were taped to enable qualitative interpretation of the transillumination data. To provide the relevant amount of cold light for the tip of the endoscope, an external light source was attached to the endoscope. Acoustic data have a sampling frequency of 24 kHz, PGG data were downsampled to 200 Hz, and the FF data have the standard video format of 25 images per second respectively. The velocity signals of the PGG signal was calculated as the first derivative. By analyzing the velocity signal we defined the beginning and end of glottal opening and closing using a 5% threshold criterion. In the acoustic data we labeled for /k/: closure onset (clon) as the second formant offset of the preceding vowel, burst (b), aspiration offset (aspoff) as the end of high frequency energy, and for /s/ frication onset (fricon) and frication offset (fricoff). The real word speech material consisted of several combinations of singleton and geminate /s/ and /k/ (geminates either tautomorphemic or heteromorphemic are considered as sequences of two identical consonants). All the clusters were preceded and followed by the vowel /i/. Each form was realized three times:

a. /#sk/, /s#k/, /sk#/; /#ks/, /k#s/, /ks#/,

b. /#ssk/, /ss#k/, /s#sk/, /ssk#/; /#kks/, /kk#s/, /k#ks/, /kks#/, /sk#s/, /ks#k/, /s#sk/, /k#ks/

c. /sk#sk/, /sk#ks/, /k#kks/, /k#kss/; /kk#ks/, /kk#ss/, /kks#k/,

d. /ssk#kk/, /kk#skk/.

RESULTS

Clusters with two consonants

As can be seen in figure 1 all clusters exhibit only one glottal opening peak. The peak always occurs during the fricative, i.e. the profiles for /sk/-clusters are rather left-skewed and the profiles for the /ks/-clusters right-skewed. This is in agreement with results from Löfqvist and Yoshioka (1980). Two different underlying strategies can explain these patterns: First, the asymmetry is caused by aerodynamic conditions. The fricative requires a higher intra-oral airflow than the stop and hence the peak glottal abduction occurs during the /s/. Second, the asymmetry might be caused by two underlying glottal opening gestures which overlap – a larger one for /s/ and a smaller one for /k/. Contrary to what has been observed in other languages (e.g. English and Swedish) /k/ is acoustically aspirated after /s/ whether separated or not by a word boundary. In Swedish (Löfqvist and Yoshioka 1980) and English (Yoshioka et al. 1981), a sequence of voiceless fricative + voiceless aspirated stop usually contained

two separate laryngeal gestures with peak glottal opening during the fricative and just before stop release. /sk/ clusters in HTB, on the other hand, just like voiceless geminates, exhibit one large glottal opening covering both the fricative and the stop. The degree of glottal opening at stop release for /sk/ (and for /kk/) is identical to that observed during the release of a single aspirated stop (Ridouane, 2003). The difference observed between HTB and the other two languages is probably due to differences in the phonological function of aspiration in these languages. HTB uses voicing as a distinctive feature whereas Swedish and English use aspiration.

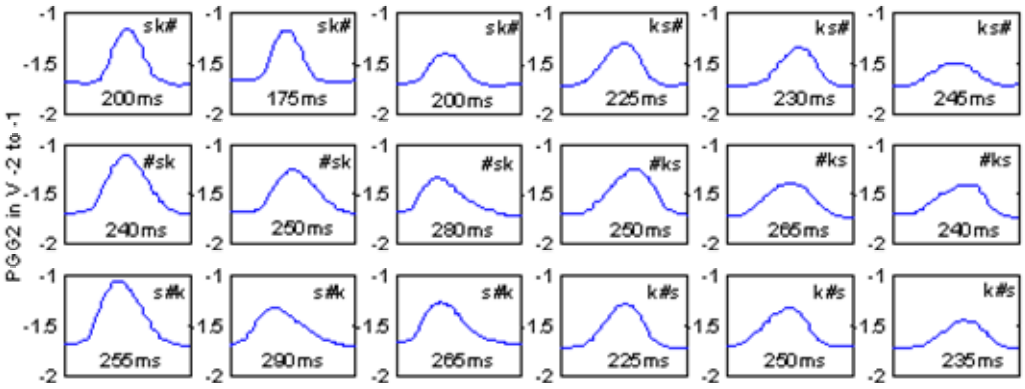

Figure 1. Glottal abduction pattern for /sk/ (column 1-3) and /ks/ clusters (column 4-6), the duration of glottal abduction in ms is written below each picture

Clusters with three consonants

- Clusters with tautomorphemic geminates

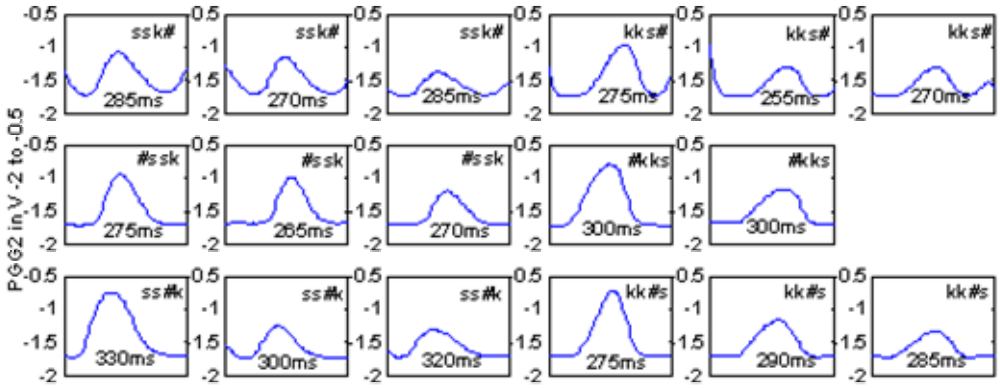

Figure 2. Glottal abduction for /ssk/ (column 1-3) and /kks/ clusters (column 4-6)

As was the case within the two-consonant clusters, all the utterance types in figure 2 are produced with one single opening gesture. The location of the peak glottal opening varies according to the phonetic nature of the voiceless obstruents and the way they are combined. The peak glottal opening during the first three sequences /ssk#, #ssk, ss#k/ is located during the geminate /ss/. For the other three sequences, the peak is almost always located at the boundary of the heteromorphemic geminate and the fricative.

Figure 3 contains the glottographic patterns for the two forms /k#ks/ and /s#sk/. The three realizations of the form /k#ks/ are not always produced with the same number of glottal gestures. Two repetitions are realized with two glottal openings and the last repetition is realized with only one. A closer examination of these three repetitions shows that for the two bi-modal realizations, the first velar was pronounced as a spirant /x/, the peak is thus located during the first velar fricative. This configuration is identical to the one observed in the three-phone combinations where the first segment and the third are fricatives. The first repetition of /s#sk/ is produced with only one large glottal opening. The two other repetitions are realized with two smaller glottal openings, the peaks of which are located during the two dental fricatives. These observations, except for the mono-modal glottal opening in one repetition of /s#sk/, are

in accordance with the observations of Löfqvist and Yoshioka (1980) and Yoshioka et al. (1981) who also showed that each fricative segment requires a glottal opening of its own. One possible explanation for the mono-modal gesture in one repetition of /s#sk/ is that this form was realized with a shorter glottal opening duration than the two others. In other words, the number of peaks is a function of the glottal opening duration. But this does not hold if we consider the data in figures 5 and 6 below. As we shall see, some sequences are produced with a long glottal opening duration (up to 420 ms) and yet only one gesture was produced.

- Clusters with heteromorphemic geminates

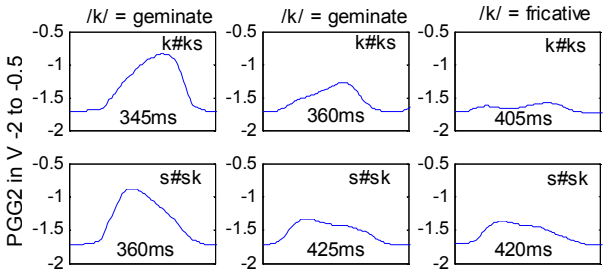

Figure 3: Glottal abduction for heteromorphemic /kks / and / ssk /

Figure 4 compares two similar three-phone combinations. The first set exhibits two glottal opening peaks. Word final /sk/ in /sk#s/ is produced with a single opening peak while the following /s/ is produced with another one. Again, peak glottal abduction is always located during the fricatives. The same configuration was also observed for /sk#s/ in American English (AE). Notice, however, that contrary to what has been observed in AE, where the first peak is generally larger than the second, in HTB the first peak may be either larger, lower or virtually equal to the second. The temporary glottal closing movement shown as a dip between peaks in row 1, is probably not a consequence of a pause due to a word boundary, since it is achieved during the stop closure. The /ks#k/ cluster is always realized with one single opening-closing gesture, with peak glottal opening located during the /s/. Similar results have also been found for AE. Here again, if we consider only the data examined so far we might suppose that the difference in the number of glottal gestures between the two sets of combinations in figure 4 is due to the overall duration of glottal opening. Sequences in row 1, with longer glottal opening durations are produced with more gestures than sequences in row 2 which are produced with shorter glottal opening durations.

- Clusters without geminates

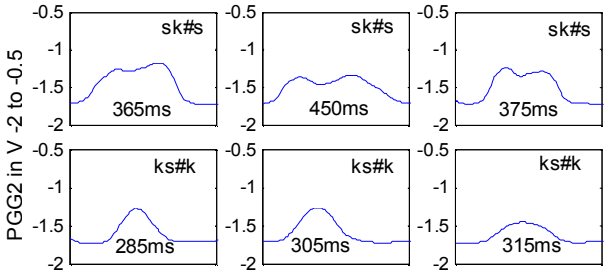

Figure 4: Glottal abduction for /sks/ and /ksk/ clusters

Clusters with four consonants

Figure 5 contains seven combinations of clusters with four consonants. The main generalization that can be drawn from figure 5 is that each geminate stop and fricative, unless adjacent, requires a single separate glottal abduction. Forms with two non adjacent fricatives are systematically produced with two glottal opening peaks, each of them located during the fricative, e.g. in /sk#ks/ and /sk#sk/. These results are in accordance with Yoshioka et al. (1981). Forms with non adjacent geminate stop + fricative also require two peaks as in /kk#ks/ where the first peak is located during the geminate and the second during /s/.

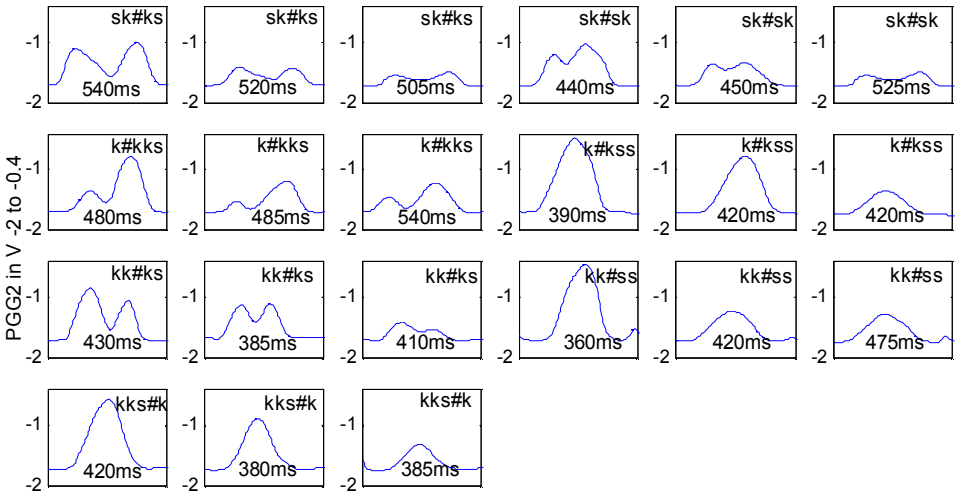

Figure 5. Glottal abduction for all clusters with 4 consonants

For forms where the geminate /kk/ (tautomorphemic or heteromorphemic) is adjacent to /s/ only one glottal opening peak is produced (see /k#kss/, /kk#ss/ and /kks#k/). The peak is always realized during the fricative. Notice that the sequences /k#kss/ and /kk#ss/ are homophonous, both forms being realized with a long closure duration followed by a release, i.e. in the first half of the heteromorphemic geminate the oral constriction was maintained and the release follows in the second half of the geminate. Similar mergers do not occur in analogous sequences in which one segment is a geminate. The sequence /k#kk/, for example, is phonetically distinct from /kk/, the first singleton velar being produced either as a stop or, if the optional spirantization rule operates, as a fricative /x/. This latter pronunciation was the one produced during the three realizations of /k#kks/, hence the two opening peaks observed during this form, the first being produced during the fricative /x/ and the second during the fricative /s/.

Clusters with five consonants

Figure 6 contains clusters of five consonants. The sequence /ssk#kk/ is produced either with two or three glottal opening peaks depending on the phonetic envelope of the singleton /k/. The form realized with a velar singleton stop exhibits only two opening peaks, one corresponding to /ss/ and the other to the closure of the geminate stop /kk/. In the two other forms, the singleton velar segment was realized as a spirant /x/, hence three glottal peaks corresponding respectively to /ss/, /x/ and /kk/. The sequence /kk#skk/ is always realized with two peaks, the first located during the /s/ or immediately after the release of the first geminate and the second during the closure of the second geminate /kk/.

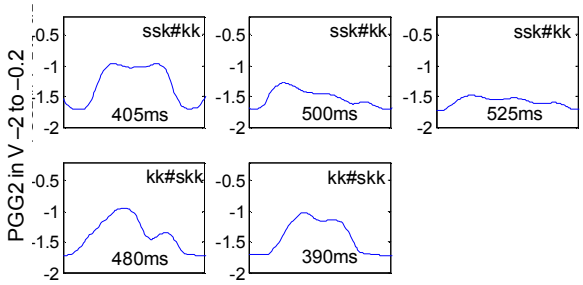

Figure 6: Glottal abduction for clusters with 5 consonants

CONCLUSION

The results of the present study, even if it is limited to a single subject, are in general agreement with those obtained using the same method and the same linguistic material in English and Swedish. We thus have further evidence from different languages that laryngeal activity during the production of

voiceless obstruent clusters is organized in one, two or more glottal opening-closing gestures. The manner of articulation of obstruents and their position in the clusters have a major impact on the number of glottal opening peaks. Word boundaries, on the other hand, do not influence laryngeal adjustment to the same extent. A good predictor of the number of glottal opening gestures occurring is that in a cluster, each fricative and geminate, unless adjacent, requires a single separate glottal abduction. The variation in laryngeal adjustments seems to be related to segmental properties of a sequence. Voiceless geminate stops and fricatives, requiring a high rate of oral air flow and build up of oral air pressure, are produced with a separate glottal opening gesture.

Since the observable patterns do not reveal unequivocally how many gestures are underlyingly present, for the next stage of the study we will try and simulate the findings by investigating what assumptions about duration, amplitude and timing of individual gestures give the best match to the measured data. This will be of particular interest for the fairly numerous cases where for the same total duration of glottal abduction different numbers of gestures were observable in the surface behaviour.

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