Subglottal pressure differences between voiceless bilabial stops and ejectives

Didier Demolin[1], Sergio Hassid[2]

[1]Laboratoire de Phonétique et Phonologie, UMR 7018 CNRS-Sorbonne Nouvelle
[2]Hôpital Erasme, Université libre de Bruxelles

https://doi.org/10.36505/ExLing-2022/13/0015/000557

Abstract

This paper presents an aerodynamic study comparing realizations of bilabial stops consonants in three languages, French, English and Amharic. Results show that subglottal pressure differs between languages and subjects within a language. An explanation is provided to explain why subglottal pressure doesn't drop as expected in ejectives.

Keywords: subglottal pressure, stops, ejectives, aerodynamics

Introduction

The respiratory system is generally regarded as producing voluntary variations in intensity but not producing voluntary increases in subglottal pressure (Ps) for particular sounds. This study assumes that there are differences in Ps between voiceless bilabial stops and ejectives. The hypothesis that difference between these pulmonic and non-pulmonic consonants is tested through measurements of glottal resistance, the Δ between Ps and intra-oral pressure (Po) and differences in Ps during VOT.

Material and method

Words and logatoms were recorded with 5 different speakers: 2 native English male speakers (1 English, 1 American), 2 French male speakers and 1 Amharic male speaker. The audio signal, oral airflow and subglottal pressure (Ps) were recorded simultaneously with the *Physiologia* workstation (Teston 1983). The audio signal was digitized at 16,000 Hz and the physiological data at 2,000 Hz. Ps was measured with a needle (ID 2 mm) inserted in the trachea. Oral airflow (Oaf) with. a flexible silicon mask, both synchronized with the audio signal. The microphone was at a quasi-constant distance of the lips. Data have been processed with the *winpitch* software.

The procedure preserved the rights and welfare of human research subjects, in respect of the ethical committee's rules (https://www.erasme.ulb.ac.be/fr/ethique).

Procedure

English and French speakers produced logatoms in a small carrier sentence including the different consonants between the vowel [a] (e.g. 'Say papa again' (5 times) or 'Dis papa encore' (5 times). Amharic data were recorded in the same context but in real words. Data were collected in simultaneous and synchronized recordings of subglottal pressure (Ps), intraoral pressure (Po) [Ps and Po measured in hPa (1 hPa = 1.2 cm H_20)] and the speech acoustic signal. The Po measure was obtained with a small flexible plastic tube inserted through the nasal cavity into the oropharynx. The same recording procedures were applied for the three languages. Ps and Po were measured simultaneously at 4 points for the voiceless stops [p^h, p] and 3 points for the ejective [p'] and voiced bilabial stop [b] that was used for the sake of comparison in English. 15 measures were made for each consonant. This is a small amount of data but the difficulty to acquire Ps justifies this quantity. The replication is possible by testing other similar data in Demolin et al. (2019).

Results

Ps measures were made at the following points: (1) at the start of the bilabial closure; (2) at the 1st Po peak; (3) at peak oral closure, just before closure release; (4) at the lowest value of Ps in the VOT. Ejectives have only 3 points of measures (start, peak, end) (Figure 6). The English voiced stop also has 3 points of measurements: at the start of the bilabial closure; at the 1st Po peak; at peak oral closure before closure release (Figure 4).

ΔPs/Po is smaller for voiceless [p] and [p^h] when compared to the voiced counterpart [b]. Ps is higher for [p^h] when compared to [b] which accounts for data taken with the 2 English speakers. Po is much higher than Ps in the ejective (up to 8.3 hPa) because of the of the vocal tract volume reduction. Ps values show a gradual increase towards peak but for the ejective [p'] which doesn't vary much between the 3 measurements points, > 9.2 hPa and < 9.6 hPa (Figures 2 to 4).

Ps values measured at the lowest point during the VOT varies between 0.5 hPa and 1.7 hPa. There is almost no drop of Ps during the ejectives VOT (0.2 hPa).

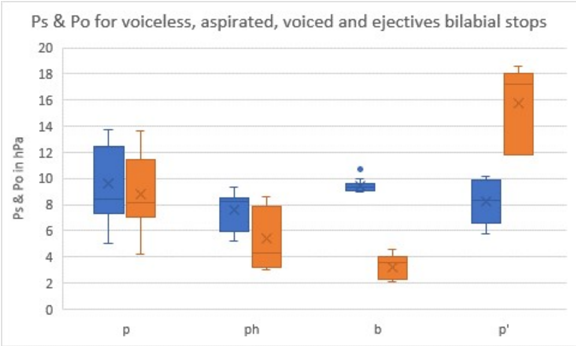

Figure 1. Ps & Po values for voiceless bilabial stops [p] in French & Amharic (n=52), voiceless bilabial aspirated stops [pʰ] in English (n=25), the Amharic bilabial ejective [p'] (n=6) and an English voiced bilabial stop [b] (n=25).

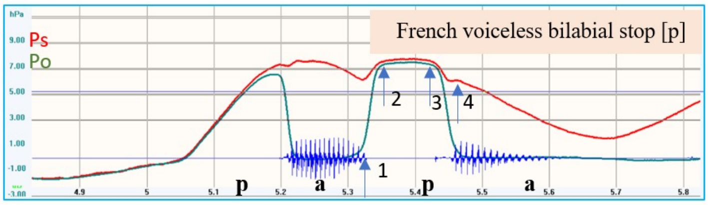

Figure 2. Audio waveform, Ps and Po for a voiceless bilabial stop [p]. 1 shows the start of the bilabial closure, 2 the full closure. Distance between 3 and 4 shows the VOT and its effect on Ps.

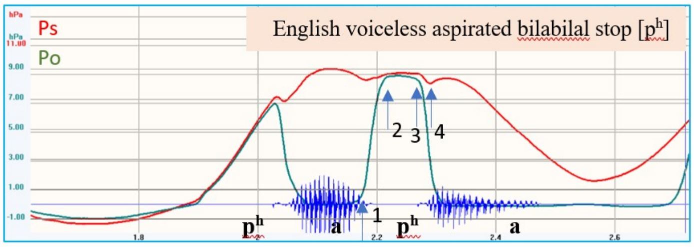

Figure 3. Audio waveform, Ps and Po for a voiceless bilabial aspirated stop [pʰ]. 1 shows the start of the bilabial closure, 2 the full closure. Distance between 3 and 4 shows the VOT and its effect on Ps.

Conclusion and perspectives

There is no clear difference between aspirated stops [pʰ] and non-aspirated stops [p] in terms of Ps and Po. Both for English and French, there is a speaker with Ps & Po values higher than the other. Two points about ejectives deserve a comment. Ps is higher for the voiced bilabial stop [b] compared to [pʰ] in English. There is a 2 hPa difference between the two sounds. Ps is rather constant during the production of [p'] and there is virtually no Ps drop during the VOT. The constant value of Ps is likely explainable by the tracheal pull effect of the larynx's rising. Indeed, it squeezes the trachea and thus acts to reduce the laryngeal tube diameter and volume. This keeps Ps higher than expected. The glottis remaining closed after the bilabial release explains the quasi absence of Ps drop during the VOT. These results confirm Löfqvist (1975) study on Swedish stops but with pulmonic and non-pulmonic stops in other languages. Similar trends are observed in alveolar and velar stops.

This short study shows that details in glottal setting between pulmonic and non-pulmonic stops depend on subtle differences in features of glottal impedance.

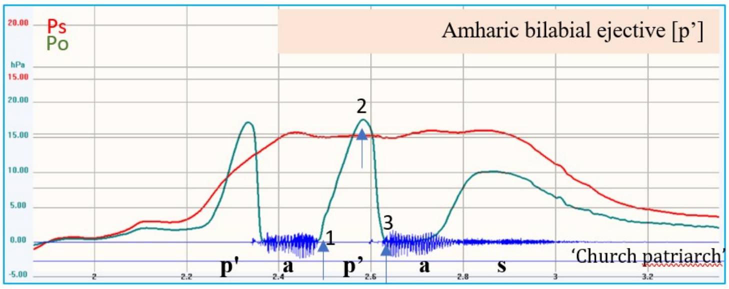

Figure 4. Audio waveform, Ps and Po for a bilabial ejective [p']. The distance between 1 and 2 reflects the time for the elevation of the larynx and the reduction of the pharyngeal cavity size. Vocal folds start to vibrate at 3 which is the time when the glottis opens as the VOT is produced with a closed glottis in Amharic ejectives.

Acknowledgements

Work supported by grants ArtSpeech (Phonetic Articulatory Synthesis, DS0707–2015) and by the French Investissements d'Avenir - Labex EFL program (ANR-10- LABX-0083) both from the French National Research Agency.

References

Löfqvist, A. 1975. A study of subglottal Pressure during the production of Swedish stops. Journal of Phonetics, 3.175189.

Demolin, D., Hassid, S., Ponchard, C., Yu, S. Trouville, R. 2019. Speech aerodynamics database. ILPGA, Paris 3.

Teston, B. and Galindo, B. 1990. The Physiologia system: Description and technical specifications.