Aerodynamics of Voiced Stop Production

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The objective of this study was to characterise aerodynamic parameters of voiced stop consonants including slope of the stop release, voice onset time (VOT), stop and release duration, and steady state characteristics of phones preceding and following the stop. Aerodynamic and electroglottographic (EGG) recordings of four normal adult speakers (two females and two males), producing a corpus of 9 isolated words with the European Portuguese (EP) voiced stops /b, d, g/ in initial, medial and final word position, and the same 9 words embedded in 39 different real EP carrier sentences, were analysed.

The slope of the stop release was calculated from linear regression, using all flow signal points from the start to the end of the release.

The slopes of the stops releases show no significantly different values for the three different places of articulation, but there was a difference of approximately 10%, for all stops, between male and female speakers (Male: 78.9%(mean)8.5%(std); Female: 69.0%(mean)11.5%(std)). An interpretation of these findings is that, as proposed by Higgins et al. (1998), glottal area and resistance affect peak oral air flow.

Bilabial stops showed higher VOT values (-58.5ms to -64.6ms) than dental and velar stops (-49.0ms to -57.6ms). Female speakers' VOT was higher than male speakers' (Male = -49.5ms(mean)36.1ms(std); Female = -58.0ms(mean)28.8ms(std)). This difference was also observed for stop durations (Male = 79.1ms(mean)28.6ms(std); Female = 92.8ms(mean)26.29ms(std)) and release durations (Male = 28.6ms(mean)11.4ms(std); Female: 35.3ms(mean)14.8ms(std)). Dental stops' duration (81.9ms(mean)28.3ms(std)) and release duration (29.5ms(mean)12.3ms(std)) were lower than bilabial and velar stops' duration (/b/: 88.2ms(mean)27.7ms(std); /g/: 87.8ms(mean)28.6ms(std)) and release duration (/b/: 34.3ms(mean)15.1ms(std); /g/: 35.5ms(mean)14.2ms(std)).

Analysis windows were defined in the three different production stages: stop closure, and steady state of phones preceding and following target stop. Absolute mean oral flow values and amplitude of oscillations were extracted from these windows for all recordings and speakers, and relative vowel-stop and stop-vowel amplitudes were computed.

A decrease in amplitude of the oral flow waveforms during the stops, relative to the amplitude of the previous and following phone, was observed for all speakers. Absolute amplitude values for female speakers were lower than for males.

By inspection of typical vowel and stop oral flow values, and from the phoneme boundaries set during the annotation phase, we define a voicing category *weak voicing* (Pinho et al. 2009) as voicing where the ratio of average airflow in the stop to that in the preceding or following phone is less than 70%.

Aerodynamic variables measurable from real speech have an impact on the mechanics of vocal fold vibration (i.e., onset and offset of vibration, opening and closing quotients of the vibratory cycle) that must be incorporated in realistic speech models. They can also be used to understand the effect of variability in stop production on the performance of stop detectors.

Higgins, M., R. Netsell and L. Schulte (1998). Vowel-Related Differences in Laryngeal Articulatory and Phonatory Function. JSLHR 41: 712-724.

Pinho, C., L. Jesus and A. Barney (2009). Aerodynamics of Fricative Production in European Portuguese. In Proceedings of InterSpeech 2009, Brighton, UK, 472-975.