Statistical Analysis of the Aerodynamics of Voiced Stop Closures

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Abstract

Introduction: Speech and Hearing Sciences is a broad and interdisciplinary field that integrates knowledge of acoustics and aerodynamics of speech production and speech perception, that is the basis of a systemic view of speech, language and hearing disorders in special populations. Views of the laryngeal feature of contrast for stops have been considerably enriched by new acoustic and articulatory phonetics evidence which strengthened arguments that in some languages, stop voicing is phonologically active and in others, it is passive [1]. A clear relation between phonetic cues and phonological processes that support this, has yet to be found.

Experimental data combining complementary measures based on the oral airflow signal, supporting the view that European Portuguese (EP) voiced stops are produced in a similar fashion to voiced stops in Germanic languages is presented in this abstract.

Methods: Recordings of four Portuguese speakers, producing a corpus of nine isolated words with /b, d, g/ in initial, medial and final word position, and the same nine words embedded in 39 different real sentences, were collected. Slope of the stop release (SLP), voice onset time (VOT), release and stop durations (RLS and STP, respectively), and steady state oral airflow amplitude characteristics preceding and following the stop, namely, amplitude of the oral airflow signal at phones 1, 2 and 3 (OA1, OA2 and OA3) and relative amplitude phone1-2 (A12) and phone2-3 (A23), were analysed.

Data analysis considered all the variables mentioned. Inferential analysis was conducted with place of articulation (PLA), sex (SEX) and vowel context (VOW) as factors and the results obtained are presented at the 0.05 significance level. Data normality analysis, comparisons between groups and correlation analysis were carried out using IBM SPSS Statistics 24. For the analysis of the correlations between SLP & VOT and RLS; SLP; A12; A23 for all stops, and then for each place of articulation, the Pearson's correlation coefficient was calculated. Statistically significant correlations were reported at the 0.05 and 0.01 significance levels. To infer about the normality of the distributions underlying the data, the Kolmogorov-Smirnov test with the Lilliefors' significance correction was run for each independent group. It was concluded that no comparison could be done in a parametric context, as the assumption of normality could not be considered to hold for any set of independent groups of data, at the 0.05 significance level. As such, comparisons between medians of any two independent groups were made using the Mann-Whitney U test, and comparisons between any three or more independent groups were made using the Kruskal-Wallis test.

As speech is a scientific subject that is inherently multidimensional and exhibiting complex interactions between multiple covariates, there have been, over the last years, many discussions concerning the best way of analysing phonetic data. In recent years, phonetic research has been moving away from simple analyses of variance (where one must compute means for each participant) and giving more credit to new approaches such as linear mixed effects models that besides allowing the inclusion of all data points produced by a participant, also accounts for both by-participant and by-item variance. Following this tendency, in this paper, mixed effects models of the mean oral airflow (MOA) were developed using the lmer function in the lme4 package in R [2]. A mixed effects model was considered with VOT, SLP and the factors PLA, SEX and VOW as the fixed effects and the results discussed.

Results: Significant correlations (details shown in Table 1) were found between SLP and RLS; SLP and A12; SLP and A23; VOT and A12, when all stops were analysed together. There were also significant correlations between the values of the steady absolute oral airflow amplitude of phones 1 and 3, OA1/OA3 (R=0.833 and p=0.000).

Table 1 Results from the correlation analysis: Number of tokens (first line); Pearson's correlation coefficient (second line); p-value (third line).

	RLS	A12	A23
SLP	106 R=-0.573** p-value=0.000	81 R=0.269* p-value=0.015	85 R=0.237* p-value=0.029
VOT	106 R=-0.015 p-value=0.877	80 R=-0.233* p-value=0.038	83 R=-0.041 p-value=0.712

** Correlation at a 0.01 significance level

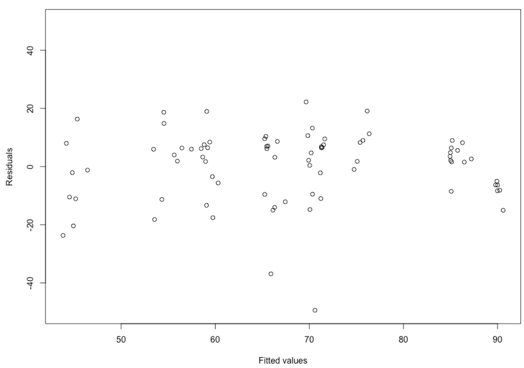
* Correlation at a 0.05 significance level

The model was fitted by REstricted Maximum Likelihood (REML) and the value of the REML criterion at convergence, which is the equivalent of the deviance for models fitted by Maximum Likelihood (ML), was 613.4. The estimated equation for the structural part was

EstimatedMOA = 78.354 - 4.586Factor(PLA)2 - 13.762Factor(PLA)3 + 1.030Factor(SEX)2 – 1.215Factor(VOW)2 -0.014VOT – 0.066SLP

The standard fitted values vs. residuals plot is presented in Figure 1 for the estimated model, suggesting no obvious deviations from homoscedasticity, with a small bias.

Figure 1 Standard fitted versus residual plot.



Discussion and conclusions: The VOT was significantly correlated to the relative amplitude of oral airflow (A12), more specifically, a longer VOT resulted in lower A12 values, meaning that those stops presented stronger voicing than those with shorter VOT values; shorter releases (lower RLS values) resulted in steeper slopes (higher SLP values), which were also significantly correlated to higher relative oral airflow values; steeper slopes (SLP) were correlated to shorter releases (RLS) in bilabial and dental stops, and to shorter (STP) dental stops.

A particularly striking (high correlation coefficient values) result was that for STP/VOT correlations: Longer stop durations clearly resulted in shorter VOT values, for all places of articulation. Higher A12 values were correlated to shorter dental and velar stops VOT, and MOA/VOT were significantly (negatively) correlated, for velar stops.

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