On the necessity of exploring individual variation

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One of the typical goals of fitting statistical models to human speech data is to make inferences about a population based on a smaller sample of participants. The results are usually aggregated across speakers, even when individual variation is accounted for in the form of random by-participant intercepts, slopes or smooths in mixed models. In the present study, we show that without carefully looking at individual variation we can erroneously (dis)confirm our hypotheses if we only rely on results from mixed models.

In our study we tested the hypothesis advanced by Hamann (2003:44) that palatalized retroflexes are non-existent in the world's languages due to the incompatibility of retroflexion and palatalization gestures on the same sound (Hamann 2002:47). Thus, according to this claim the retroflexes /ʂ, ʐ, t͡ʂ, d͡ʐ/ change to palato-alveolars when being palatalised (see also Hamann 2003:46).

Polish offers a useful case to test this claim. In this language, the plain retroflexes /ʂ, ʐ, t͡ʂ, d͡ʐ/ are palatalised if they appear before /j, i/. Under the aforementioned hypothesis about the non-existence of palatalized retroflexes, the outputs of this rule are expected to be palato-alveolar [ʃ ʒ t͡ʃ d͡ʒ]. To test this prediction, we investigated 20 speakers of Polish (aged 22 to 46; 10 women, 10 men) by means of EMA. Our stimuli consisted of palatalized retroflexes (voiced and voiceless fricatives and affricates) appearing in word-initial and word-medial position with stress falling on the penultima, e.g. dżinsy [d͡ʐʲiɲsɨ] "jeans", czipsy [t͡ʂʲipsɨ] "chips. For reasons of comparison we also recorded plain retroflexes in the same word and stress positions. In total, 840 tokens contrasting palatalized and plain retroflexes were obtained.

For the statistical analysis, we employed linear mixed models by using the R package lme4 (Bates et al. 2019, version1.1-21). The outcome variable was the sensor measurement (tongue tip – TT, tongue front – TF, tongue dorsum – TD, tongue back – TB and tongue's left side TLS) and the predictors include segment type, palatalisation, their interaction, stress and sex. In addition, the models include random intercepts by word and by speaker, random slopes over segment, palatalisation, and their interaction by speaker. The full model formula is provided in the Appendix.

The results showed that palatalised retroflexes are produced with a higher and more convex dorsum in comparison to plain sibilants (see Figure 1) confirming the initial hypothesis about the palato-alveolars being the outputs of the palatalization rule and the non-existence of palatalised retroflexes. The latter are expected to be produced with the tongue tip touching the postalveolar place of articulation, a sublingual cavity and retracted tongue back resulting in a flat or even concave tongue shape.

However, looking at the individual productions lead us to different results. Some of our speakers do indeed seem to produce palato-alveolars with a typical convex tongue shape being higher than the plain counterpart (Figure 2a). But some of them realise palatisation with a flat (Figure 2b) or concave tongue shape (Figure 2b), being typical retroflexes. The results are summarized in Figure 3 and illustrated in videos based on smoothed estimated of sensor movements over time generated via Generalised Additive Mixed Models (GAMMs, see: https://osf.io/k9gv5/?view_only=673674444ac74e929e3831fe1aaad8f5)

Thus, we concluded that palatalised retroflexes in Polish are realised with a convex, flat and concave tongue shape, with the latter two production strategies likely corresponding to palatalised retroflex articulations. This finding, in turn, leads us to ultimately reject the initial hypothesis and conclude that palatalised retroflexes do exist. When focusing on fixed effects estimates from mixed models, as is typical in phonetics, their existence in individual speakers is masked by the group-level patterns. We therefore encourage analysts not to ignore individual variation, which is readily available for inspection not only in the raw data but also in the random effects estimates of mixed models.

Appendix:

(1) Formula: sensor measurement ~ segment type * palatalisation + voicing + stress + sex + (1 + segment type * palatalisation | speaker) +(1 | word)

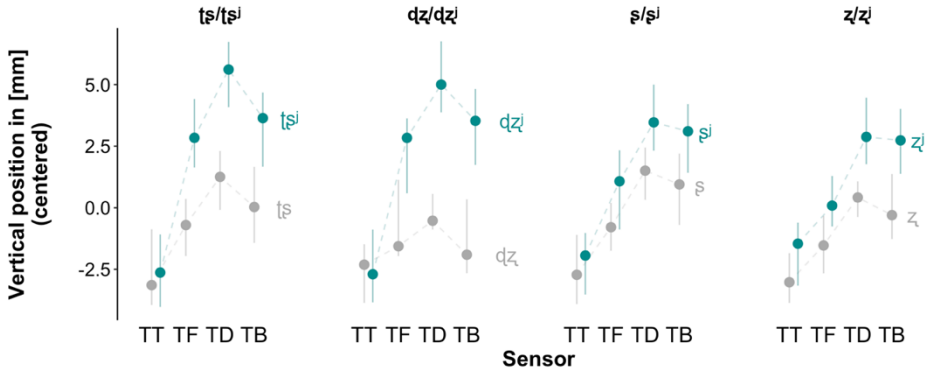

Figure 1: Vertical movement of TT, TF, TD and TB sensors for palatalised and plain sibilants

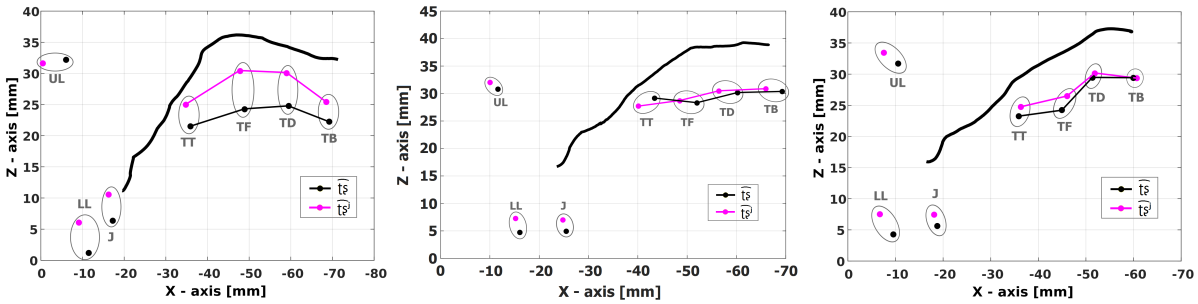

Figure 2: EMA sensors with the tracing of the palate (black line) for [t͡ʂ] (black dots) and [t͡ʂʲ] (pink dots): convex tongue shape, speaker F7 (left), flat tongue shape, speaker M8 (middle), concave tongue shape, speaker F9 (right)

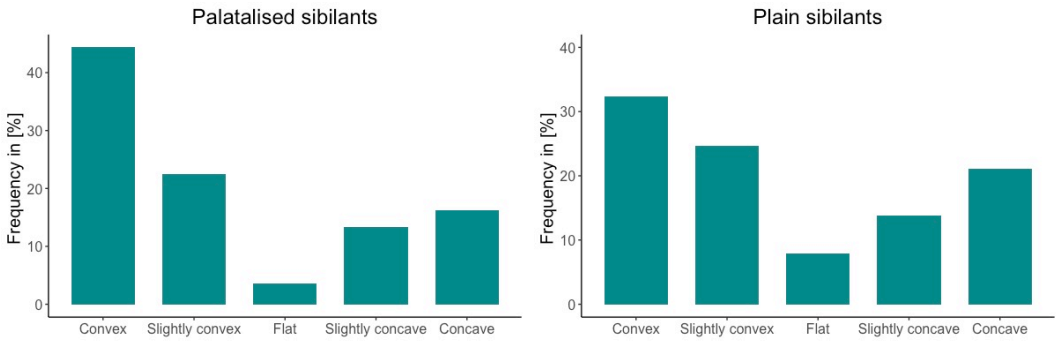

Figure 3: Frequency of occurrence of different tongue shapes in the palatalised (left) and plain sibilants (right)

References:

Bates, D., Maechler, M., Bolker, B., & S. Walker.2019. lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1-21., https://CRAN.R-project.org/package=lme4.

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