

Distance vs. time: articulatory trade-off in Polish vowel reduction

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Background: There is generally a correlation between temporal and spatial gestural reduction, although it is understood that this relationship is also modulated by a variety of factors. We study this issue in the context of phonetic vowel reduction in Polish.

Methods: The data are time-synchronised audio and midsagittal ultrasound recordings from 10 native speakers of Polish (9 females, mean age = 32). We elicited vowel reduction in two ways: by manipulating stress (e.g. *mimo* /'mi.mo/ 'despite' vs. *mimoza*, /mi.'mo.za/ 'mimosa', and by manipulating speech rate through instruction to participants (slow, normal and fast). The segmental environment was controlled for. All six oral vowel phonemes were included (*i* /i/, *e* /e/, *a* /a/, *o* /o/, *u* /u/, *y* /ɨ/) appearing in stressed, and pre-stressed positions. 144 tokens were collected from each participant. Formants were extracted automatically in Praat at acoustic midpoint and normalised using *z*-score. Midsagittal tongue contours were extracted at the same time point in Cartesian coordinates. They were then submitted to a Principal Component Analysis, applied by-speaker (Turton, 2015) and reduced to two PCs, which typically accounted for more than 90% of the variance. In order to standardise the rotation and scaling of the PCs, the PCs were entered as predictors in linear models of normalised *f1* and *f2* (for each speaker; this method is a modified version of Mielke et al (2017). The measurements, PCs and normalised PCs, are illustrated in Figure 1, for speaker PL01, along with mean tongue contours and formant measurements.

We then modelled the formants and the normalised PCs, along with V1 duration using linear mixed models in lme4.

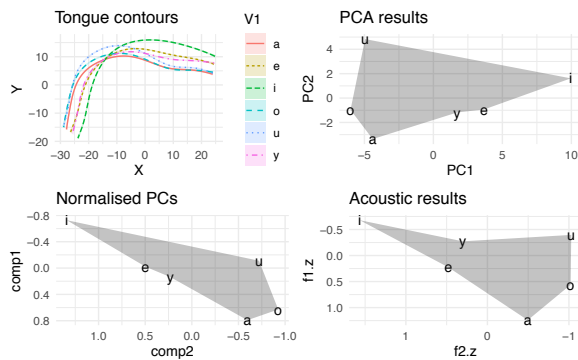


Figure 1: Normalisation for PL01

Results and discussion: The results show that vowel duration is systematically affected by both speech rate manipulations and stress. Accordingly, the acoustic vowel space is systematically contracted from slow, through normal, to fast speech rate, and from stressed syllables to unstressed ones (Figure 2). In contrast, only speech rate systematically affects normalised PCs, but there is no systematic difference between normalised PC values in stressed and unstressed syllables (Figure 3). This suggests that the acoustic vowel reduction we find in unstressed syllables is due to a different articulatory mechanism than acoustic reduction at relatively faster speech rates. We propose, tentatively, that some of the acoustic findings can be explained by larynx raising to mark stressed syllables.

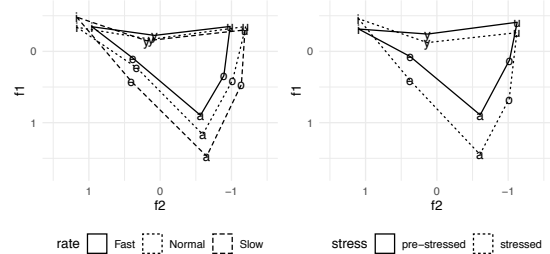


Figure 2: Normalised acoustic vowel spaces

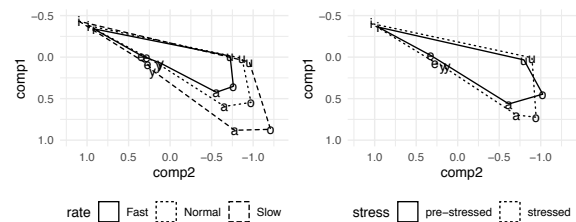


Figure 3: Normalised articulatory vowel spaces

In a broader perspective, our results show that prosodic factors, such as stress, can systematically affect the correlation between temporal and spatial reduction. While this is well established in languages with phonological vowel reduction, Polish seems to represent the opposite end of the spectrum, i.e. there is less spatial reduction in unstressed vowels than would be expected from the degree of temporal reduction we observe.

References

- Mielke, J. C. Carignan, and E. R. Thomas. "The articulatory dynamics of pre-velar and pre-nasal /æ/-raising in English: An ultrasound study". In: *The Journal of the Acoustical Society of America* 142 (2017).
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