Prosodic variation in a multi-dimensional dynamic system

Simon Roessig & Doris Mücke
IfL – Phonetik, Universität zu Köln

The research literature in the fields of phonetics and phonology is rife with reports on the variability of prosodic patterns. In particular, one can identify two types of variation [1]: on the one hand categorical variation in the form of a probabilistic mapping of what has been agreed upon as prosodic categories can be found [2]. While, for example, a particular pitch accent type is used to express a pragmatic meaning most of the time, also other pitch accents can be found to be employed for the same function. On the other hand, a great deal of continuous variation within the prosodic categories has been shown. For example, the pitch excursion of an accent can be varied systematically in association with a pragmatic function [3]. It has been suggested that the two types of variation work in symbiosis and can be exploited by speakers flexibly [1].

A growing body of research demonstrates that prosodic variation affects all levels of speech production including the articulatory domain (e.g. [4–6]). Prosodic prominence is expressed by systematic adjustments of the *supra-laryngeal* articulation, i.e. by increasing articulatory effort in prominent syllables to produce longer and larger movements of the tongue, jaw and lips. More recently, it could be shown that systematic variation on the hypo-hyper-articulation continuum is not only modulated by the presence or absence of a pitch accent. Rather, speakers seem to use continuous prosodic variation to directly encode functions like different focus types [7]. Since prosodic variation is so pervasive on all levels of speech, the aim of this study is to bring together the laryngeal-tonal aspects and the supra-laryngeal-articulatory aspects of prosodic variation and propose a modelling account that integrates both. Therefore, we recorded and analysed a corpus of 27 German native speakers with 3-D Electromagnetic Articulography who produced sentences with varying focus structures (broad, narrow, contrastive focus, and background).

Fig. 1 presents results of two parameters from our analysis: (a) shows the results for the tonal onglide – a laryngeal parameter characterising the f0 movement towards the main target of the pitch accent (negative values indicate falling accents, positive values indicate rising accents). The proportion of rising accents increases when going from broad focus to narrow focus, and finally to contrastive focus. The proportion of the pitch accent categories varies systematically between the focus types as well as the medians of the riding distributions indicated by the black dots. The measure of the lip aperture (b) shows a similar picture of continuous variation with increasing values from broad to narrow focus to contrastive focus.

We employ an *attractor-based* modelling approach rooted in the framework of dynamic systems theory. Dynamic systems have proven to be a powerful tool in understanding human cognition in general and patterns of speech in particular [8–11]. While these systems work in a completely continuous environment, they offer the concept of attractors to describe stability and (near-)categorical behaviour. We model the prosodic system as a multi-dimensional attractor landscape, like the one exemplified in Fig. 2, in which the attractors come into being by the patterns of stability and variability on the various dimensions. Crucially however, the system is governed by a *single* control parameter. By scaling this control parameter, the attractor landscape is shaped, attractors become more or less stable or slightly shift their location. Compare the *left* panel of Fig. 2, where the control parameter is 0 to the *right* panel where it is increased to 4: both the probability of rising accents, as well as the magnitude of the tonal onglide and the lip aperture is increased.

Our model integrates tonal and articulatory variation of prosodic prominence. By capturing both, categorical variation as well as continuous variation, it contributes to the understanding of phonetics and phonology as one system [12].

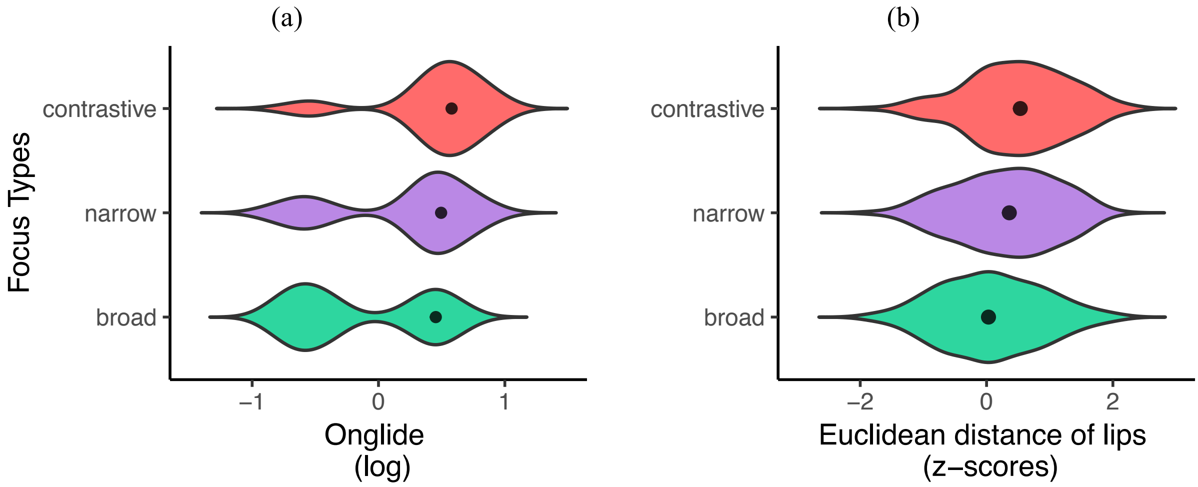

Figure 1. *Results of the measures (a) tonal onglide and (b) lip aperture. Black dots indicate medians of the distribution – in the case of tonal onglide only the rising distributions.*

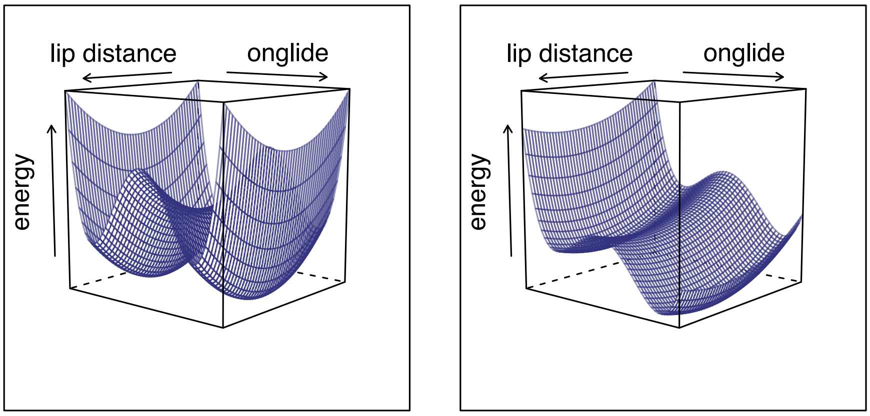

Figure 2. *An example attractor landscapes of the multi-dimensional modelling approach with varying control parameter values k: left k = 0; right k = 4.*

1. Ladd DR. Simultaneous structure in phonology. Oxford: Oxford University Press; 2014.
2. Roettger TB, Cole J. Mapping prosody onto meaning – the case of information structure in American English. 2018. Preprint: https://psyarxiv.com/tevd6/
3. Grice M, Ritter S, Niemann H, Roettger TB. Integrating the discreteness and continuity of intonational categories. J Phon [Internet]. 2017;64:90–107. Available from: http://www.sciencedirect.com/science/article/pii/S0095447017300566
4. Harrington J, Fletcher J, Beckman ME. Manner and place conflicts in the articulation of accent in Australian English. In: Broe M, editor. Papers in laboratory phonology V: Acquisition and the Lexicon. Cambridge: Cambridge University Press; 2000. p. 40–51.
5. Cho T, M. McQueen J. Prosodic influences on consonant production in Dutch: Effects of prosodic boundaries, phrasal accent and lexical stress. J Phon. 2005;33(2):121–57.
6. Mücke D. Dynamische Modellierung von Artikulation und prosodischer Struktur: Eine Einführung in die Artikulatorische Phonologie. Berlin: Language Science Press; 2018.
7. Mücke D, Grice M. The effect of focus marking on supralaryngeal articulation - Is it mediated by accentuation? J Phon. 2014;44:47–61.
8. Spivey M. The Continuity of Mind. New York: Oxford University Press; 2007.
9. Gafos AI, Benus S. Dynamics of Phonological Cognition. Cogn Sci [Internet]. 2006;30(5):905–43. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1207/s15516709cog0000_80
10. Tuller B, Case P, Ding M, Kelso JAS. The nonlinear dynamics of speech categorization. Vol. 20, Journal of Experimental Psychology: Human Perception and Performance. 1994. p. 3–16.
11. Browman CP, Goldstein L. Articulatory phonology: an overview. Phonol Yearb. 1986;3:219–52.
12. Port RF. Dynamical Systems Hypothesis in Cognitive Science. In: Encyclopedia of Cognitive Science. Nature Publishing Group; 2002. p. 1027–32.