Journal of Phonetics 65 (2017) 1–14

Contents lists available at ScienceDirect

Journal of Phonetics

journal homepage: www.elsevier.com/locate/Phonetics

Research Article

Articulatory mechanisms underlying onset-vowel organization

Manfred Pastätter *, Marianne Pouplier

Institute of Phonetics and Speech Processing, Schellingstraße 3, D-80799 Munich, Germany

ARTICLE INFO

Article history:
Received 1 September 2016
Received in revised form 17 February 2017
Accepted 22 March 2017
Available online 9 June 2017

Keywords:
Gestural model
Articulatory timing
Coarticulation resistance
Onset-vowel timing
CV overlap
Polish
Coupling strength

ABSTRACT

Previous research on articulatory correlates of syllable structure suggests that the temporal organization of syllables varies as a function of the segmental make-up of the onset cluster, yet there is currently little understanding of the details conditioning this variation. We pursue the hypothesis that consonantal coarticulation resistance is one such segment-based determinant of onset-vowel timing. In order to test this we recorded articulography data for Polish and systematically varied the coarticulation resistance of C2 in #C1C2V clusters. We examined singleton and cluster onsets with different vowel-adjacent consonants in terms of temporal lag measurements as done in previous studies as well as in terms of tongue body position measurements. Both analyses revealed parallel results and substantiate the hypothesized interaction of coarticulation resistance of the vowel-adjacent consonant and onset-vowel organization. We discuss how this interaction between articulator dominance and temporal overlap can be modeled within the gestural approach to syllable organization by giving a novel interpretation to the coupling strength parameter in terms of coarticulation resistance.

1. Introduction

Finding phonetic correlates in syllable organization has engaged phonetic studies for many years since it is difficult to tease apart universals in speech planning from language-specific and segmental composition effects. The goal of the present study is to shed light on how the segmental make-up of a consonant cluster may affect cluster-vowel organization. In particular we will focus on the coarticulation resistance of the consonant adjacent to the vowel (C2 in a #C1C2V sequence) as one possible factor conditioning differences in the timing of complex syllable onsets relative to the syllable nucleus.

Regarding the articulatory organization of the syllable, systematic timing differences have been found depending on whether the consonant precedes (#CV) or follows the vowel (VC#). In a CV sequence, the movement onset for the vowel will occur before the consonant has reached its target, leading to a considerable degree of overlap, while a coda consonant will – with some exceptions – show considerably less vowel overlap (de Jong, 2003; Krakow, 1999; Löfqvist & Gracco, 1999). There is also some evidence that the organization of consonantal gestures with respect to the vowel differs as a function of syllable complexity (e.g. Browman & Goldstein, 1988; Byrd, 1995; Honorof & Browman, 1995). By comparing the timing of a cluster onset relative to a corresponding singleton onset, it has been demonstrated that at least in certain circumstances onset-vowel timing reorganizes dynamically when onset complexity increases (i.e. CV → CCV). What is meant by reorganization is illustrated schematically in Fig. 1: The vowel-adjacent /m/ in the cluster condition (bottom panel) starts later in time compared to /m/ in the singleton condition (top panel). The dashed line indicates the temporal midpoint of the singleton (top) and the cluster (bottom) onset, while the solid line indicates the constant anchor point relative to which the timing of the onset consonants is typically evaluated. This relative temporal shift between singleton and cluster induces the /m/ in *szmata* [ʃmata][1] to overlap more with the vowel compared to the /m/ in *mata* [mata]. This has been interpreted as the onset being coordinated to the vowel as a single prosodic unit: while the temporal relationship to the vowel of each individual consonant changes with increasing complexity, the timing of the onset as a whole remains the same. Within the gestural model of

* Corresponding author.
E-mail addresses: manfred@phonetik.uni-muenchen.de (M. Pastätter), pouplier@phonetik.uni-muenchen.de (M. Pouplier).

http://dx.doi.org/10.1016/j.wocn.2017.03.005
0095-4470/

[1] It has to be noted that different IPA symbols are used in the literature for the Polish post-alveolar sibilant in question, i.e. /ʃ/ (e.g. Gussmann, 2007; Jassem, 2003) and /ʂ/ (e.g. Bukmaier & Harrington, 2016; Hamann, 2004; Żygis & Hamann, 2003). In this paper, we use the symbol /ʃ/ throughout.

syllable structure, this 'global' onset-vowel organization has been termed the "C-center" effect (Browman & Goldstein, 1988, 2000).

The C-center effect is by hypothesis a universal correlate of syllable structure (Goldstein, Byrd, & Saltzman, 2006) and empirically it has by and large been confirmed for several clusters and languages (American English: Browman & Goldstein, 1988; Byrd, 1995; Honorof & Browman, 1995; Marin & Pouplier, 2010; German: Pouplier, 2012; Italian: Hermes, Mücke, & Grice, 2013; Romanian: Marin, 2013; Marin & Pouplier, 2014; but see Brunner, Geng, Sotiropoulou, & Gafos, 2014). However, some onset clusters showed other timing patterns than the expected C-center, suggesting an interaction of cluster composition and cluster-vowel organization in ways not accounted for by the gestural model of syllable structure. In particular, certain clusters fail to show the characteristic increase of onset-vowel overlap as a function of onset complexity. Yet it remains unclear which factors exactly may condition these deviating patterns. In the present paper, we propose that the coarticulation resistance of the vowel-adjacent consonant may be one of these factors. Since the concept of C-center organization is based on the observation that generally CV overlap increases with increasing onset complexity, it is conceivable that this may be blocked if C2 is highly coarticulation resistant. However, current articulatory models of syllable structure do not foresee such an interaction between articulator (spatial) dominance and degree of temporal overlap. We focus on Polish in our current study, since Polish phonotactics allow for a great variety of consonant combinations in onsets. This enables us to carry out a systematic investigation of articulatory mechanisms which may interact with cluster-vowel timing. Specifically, we compare onset clusters with vowel-adjacent consonants which are known to differ in their coarticulatory resistance: sibilants, alveolar laterals (which tends to be a 'clear' [l][2] in Polish; Rochoń, 2000) and nasals, and labial stops. These analyses allow us to determine how different degrees of coarticulation resistance affect the temporal organization of CV sequences in singleton and cluster onsets. The focus of the present study is on coarticulation resistance of C2 since this is the locus at which we can expect to find the greatest effect on onset-vowel overlap. In the following we will summarize the gestural model of syllable structure as proposed within Articulatory Phonology and review previous studies that have investigated cluster-vowel timing in a similar fashion to the current study.

1.1. Gestural coupling model

Articulatory Phonology models phonological representations of speech sounds in terms of the spatiotemporal coordination of articulatory gestures (e.g. Browman & Goldstein, 1992). Articulatory gestures specify vocal tract actions for the production of speech sounds (e.g. a lip closure for /p/ or the combination of lip closure and velum lowering for /m/). Larger

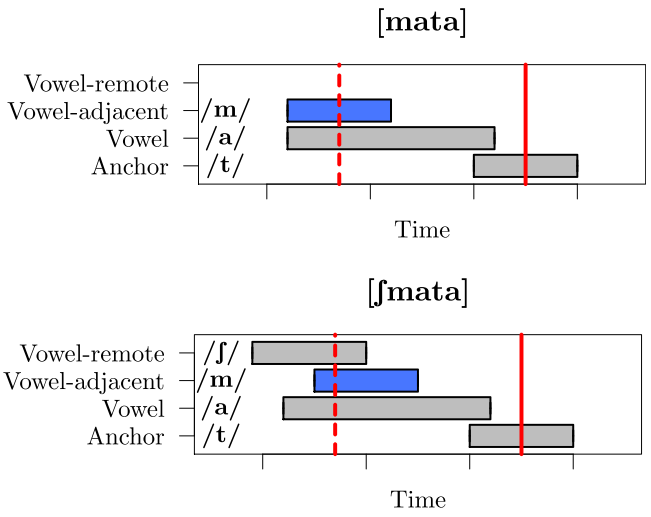

Fig. 1. Schematic representation of the predicted "C-center" organization of singleton (top) and cluster (bottom) onsets in [mata] and [ʃmata], respectively, relative to a constant anchor point, in this case /t/. Each box represents the temporal interval during which a given structure is active.

phonological units such as syllables arise from coupling relations between gestures. These coupling relations are specified for particular phase relationships. The observation that in CV sequences, consonant and vowel gestures show a high degree of CV overlap and near-synchronous movement initiation (de Jong, 2003; Löfqvist & Gracco, 1999; Nam, Goldstein, & Saltzman, 2009) is captured in the model in terms of a 0° phase relationship between onset consonant and vowel. In the case of onset clusters, not all consonants can be produced synchronously (or 'in-phase') with the vowel, since this would result in a simultaneous production of C1 and C2. The C-center organization (Fig. 1) represents a compromise solution to prevent the perceptual masking of one of the consonants: figuratively, the vowel-adjacent consonant shifts towards the vowel (i.e. /m/ overlaps more with the vowel in [ʃmata] than in [mata]) while the vowel-remote consonant (i.e. /ʃ/) shifts away from the vowel. This is so because by hypothesis onset clusters have competing phase relationships: while both consonants are coupled in-phase with the vowel, they are coupled anti-phase with each other (Browman & Goldstein, 2000; Goldstein, Nam, Saltzman, & Chitoran, 2009; Nam et al., 2009). These conflicting underlying phase specifications cannot be satisfied at the same time. The result is a blended output giving rise to the C-center timing pattern described above (Fig. 1).

To infer the underlying coordination (or phase) relationship of syllables with complex onsets, cluster-vowel timing has often been investigated relative to a corresponding singleton condition, as already discussed in the context of Fig. 1. The relative change of the temporal lag between the vowel-adjacent consonant and a constant anchor point (usually a consonant following the vowel, i.e. the /t/ in [mata] and [ʃmata]) from singleton to cluster condition is used as an index to consonant–vowel overlap. If the temporal distance between the vowel-adjacent consonant and the anchor point is shorter in the cluster compared to the singleton condition, this is taken to mean that the overlap between consonant(s) and vowel increases with increasing onset complexity (i.e. C-center organization;

[2] Laterals are characterized by a tongue tip and a tongue body constriction. Depending on the target position of the tongue body movement laterals are characterized auditorily as 'clear' or 'dark': clear laterals have a fronted and raised tongue body whereas 'dark' /l/ features a retracted and lowered tongue body (e.g. Browman & Goldstein, 1995; Sproat & Fujimura, 1993). Clear laterals are for instance typical for German, Romanian, and Polish (Recasens, 2012; Rochoń, 2000).