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Research Article

A study on coarticulatory resistance and aggressiveness for front lingual consonants and vowels using ultrasound

Daniel Recasens[a,b,*], Clara Rodríguez[a,b]

[a] Departament de Filololgia Catalana, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain
[b] Institut d'Estudis Catalans, c/Carme, 47, Barcelona 08001, Spain

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ABSTRACT

A new method for quantifying contextual variability at different regions of the tongue using ultrasound spline data reveals that tongue body coarticulatory resistance for Catalan consonants and vowels in VCV sequences decreases in the progression [ʎ, ɲ, ʃ] > [s, ɾ] > [l, ɾ, t, n] > [ð] and [i, e] > [a] > [o] > [u]. These consonant and vowel hierarchies support the degree of articulatory constraint model of coarticulation according to which coarticulatory resistance depends on whether a given lingual region is involved in the formation of a closure or constriction and on the severity of the manner of articulation requirements. Data show that this coarticulatory scenario holds not only at the palatal zone, as revealed by previous coarticulation studies, but at the velar and pharyngeal zones as well. Partial exceptions are [s] and [i], which may allow for some more contextual variability than expected at the back of the vocal tract. Another major finding is that tongue body coarticulatory resistance and aggressiveness are highly positively correlated. The implications of these experimental results for speech production organization and sound change are discussed.

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1. Introduction

Attention has been paid to the notions 'coarticulatory resistance' and 'coarticulatory aggressiveness' (also referred to as 'coarticulatory dominance') in the phonetics literature, namely, to whether consonants and vowels allow more or less coarticulation from adjacent segments, and whether those phonetic segments that are more resistant exert stronger coarticulatory effects on neighbouring phonetic segments than those that are less resistant (Fowler & Saltzman, 1993, Iskarous et al., 2013). Coarticulatory resistance is inversely related to coarticulatory sensitivity, i.e., a given phonetic segment becomes resistant the more it blocks changes in articulatory configuration exerted by the contextual phonetic segments in speech. For example, data on tongue dorsum coarticulation reveal that, in comparison to the alveolar nasal stop [n], the palatal nasal [ɲ] is at the same time more resistant to the influence of the contextual vowels and more aggressive regarding the consonant-to-vowel effects (Recasens & Espinosa, 2009). In particular, differences in tongue dorsum height as a function of [i] vs [a] are greater during [n] than during [ɲ] mostly because [i] causes tongue dorsum raising to take place during the alveolar consonant while [a] causes little tongue dorsum lowering to occur during the palatal consonant. On the other hand, effects from [ɲ] and [n] during adjacent [i] are small while those on the low vowel [a] are larger for the former consonant than for the latter and involve tongue dorsum raising. Regarding vowels, high front [i] happens to be more resistant than [a, u] to tongue body coarticulatory effects from consonants (see above), while causing greater changes in tongue body position on consonants like [n] (Chen, Chang, & Iskarous, 2015).

According to the degree of articulatory constraint model of coarticulation (DAC), coarticulatory resistance and aggressiveness for a given articulatory structure depend directly on whether this articulator takes part in constriction or closure formation and also on the specific manner of articulation demands for the target segment (Recasens, Pallarès, & Fontdevila, 1997). Thus, as revealed by the studies just cited, palatal consonants are more constrained than several dentoalveolars since the involvement of the tongue dorsum (i.e., the superior surface of the tongue behind the blade) should constrain to a large extent the tongue body (i.e., the whole tongue from tip to root), while the formation of an apical or laminal closure or constriction leaves the tongue dorsum, postdorsum and root

* Corresponding author.
E-mail addresses: daniel.recasens@uab.es (D. Recasens), claraisabel.rodriguez@uab.cat (C. Rodríguez).

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freer to coarticulate with the adjacent phonetic segments. Regarding vowels, palatal [i] and [e] ought to exhibit a higher degree of tongue constraint than the non-palatal vowels [a, o, u], which are articulated with a back lingual constriction and leave the front dorsum relatively unconstrained. On the other hand, specific manners of articulation such as frication and trilling impose strict demands on the tongue body, thus rendering lingual fricatives and trills more constrained than stop and nasal consonants of the same or a similar closure or constriction location (Recasens, 1999; Solé, 2002; Martins, Carbone, Silva, & Teixeira, 2007; Zharkova, Hewlett, & Hardcastle, 2012). Also, to the extent that they are produced with a large degree of constriction width and perhaps less control on constriction degree, approximants such as [ð˔] or [ɣ˔] ought to be less constrained than the cognate stops [d] and [g].

The study of coarticulatory resistance and coarticulatory aggressiveness has relevant implications for our knowledge about the planning mechanisms of phonemic units in speech production and about the regularities underlying sound changes involving adjacent phonetic segments (i.e., assimilations). Regarding the former issue, it provides information about the degree to which articulatory gestures for consecutive phonetic units may overlap over time and whether gestural overlap is mostly anticipatory (and thus occurs from right to left) or carryover (from left to right). As for the latter issue, the typology and direction of assimilatory processes in VC and CV sequences have been shown to reflect analogous characteristics to those observed in the V-to-C and C-to-V coarticulatory patterns (Recasens, 2014a).

The present study tests the hypothesis that lingual coarticulatory resistance and coarticulatory aggressiveness should be positively related using ultrasound data on Catalan symmetrical VCV sequences with the front lingual consonants [ð, l, ɾ, t, n, s, r, ʎ, ɲ, ʃ] and the vowels [i, e, a, o, u]. Several aspects of the articulation of these linguistic sounds need to be pointed out. In Catalan, the stop consonant [t] is dentoalveolar and the approximant [ð], which is how /d/ is usually realized in syllable onset position after a vowel, a fricative or a rhotic (*cada* "each, fem.", *esdevenir* "to become", *verda* "green, fem."), is purely dental. Catalan parallels Spanish regarding the highly frequent or systematic approximant realization of the allophone [ð] of /d/ in intervocalic position and therefore the presence of a well-defined formant structure without superimposed frication (Martínez Celdrán & Fernández Planas, 2007), which accounts for why no diacritic is appended to this phonetic symbol throughout the paper. The two rhotics are realized as an alveolar tap ([ɾ]) and an alveolar trill ([r]), and [ʎ, ɲ, ʃ] are palatal ([ʃ] is a palatoalveolar fricative and [ʎ, ɲ] are alveolopalatal). The fricative [s] and nasal [n] are plain alveolars. The spectral characteristics of the alveolar lateral as produced by the five speakers who took part in the recordings of the present investigation show that this consonant is clear rather than dark: spectrographic analysis of the symmetrical sequences [ili, ele] reveals the presence of an F2 frequency for the alveolar lateral about 1250–1550 Hz for males, and about 2500 Hz ([i] context) and 1600–1800 ([e] context) for females (regarding the spectral structure of clear /l/ for female speakers, see Karlsson (1994)). These front lingual consonants also differ regarding the primary articulator, i.e., [t, n, s] are generally apicolaminal, [ð] and [l, ɾ, r] are apical, and [ʎ, ɲ, ʃ] are laminopredorsal.

A good reason for using ultrasound data for the analysis of lingual coarticulation is in order to verify whether the predicted differences in coarticulatory resistance and aggressiveness among consonants and vowels hold not only at the tongue front and dorsum and thus at the alveolar and palatal zones, as shown by previous electropalatographic (EPG) and electromagnetic articulometer (EMA) studies, but also at the tongue postdorsum and root and thus at the velar and pharyngeal zones. Another advantage of ultrasound in comparison to EPG and EMA is that it provides information about tongue position at a large number of flesh points and therefore allows us to measure coarticulatory patterns more precisely.

A large scale ultrasound study on lingual coarticulation for several consonants and vowels such as the present one was lacking in the phonetics literature (previous ultrasound studies such as Zharkova and Hewlett (2009), Zharkova, Hewlett, and Hardcastle, (2011, 2012) and Noiray, Ménard, and Iskarous (2013) have dealt only with lingual fricatives and less so stops). This paper investigates the patterns of lingual coarticulatory resistance and aggressiveness for a more complete set of Catalan front lingual consonants and vowels than in previous EMA and EPG studies, where only [l, n, s, ɲ, ʃ] and [i, a, u] were subject to investigation and more attention was paid to coarticulatory resistance than to coarticulatory dominance (Recasens & Espinosa, 2009). The articulatory analysis of some additional front lingual consonants and vowels, i.e., [ð, ɾ, t, r, ʎ] and [e, o], should contribute to a better understanding of how mid vowels and constriction degree, laterality and rhoticity for consonants contribute to the overall coarticulation scenario.

Given the place, manner and articulatory constraint characteristics of the Catalan front consonants and vowels described above, several predictions may be formulated about the degree of coarticulatory resistance and aggressiveness that these phonetic segments ought to show in symmetrical VCV sequences:

(a) Regarding place of articulation, coarticulatory resistance and aggressiveness ought to be higher for palatal consonants articulated with the tongue predorsum or with the blade and predorsum ([ʎ, ɲ, ʃ]) than for dentoalveolars produced with the tongue tip or tongue tip and blade ([ð, l, ɾ, t, n, s, r]). In addition to Catalan, this trend has been found to hold for English ([ʒ] > [ð, d, z], Fowler & Brancazio, 2000), German ([ʃ] > [t, d, n, s, l], Hoole, Gfroerer, & Tillmann, 1990) and Australian languages ([c]>[t], Butcher & Tabain, 2004). Likewise, among vowels, the palatals [i, e] should be more resistant and aggressive than the non-palatals [a, o, u], as also found for [i] vs [a, u] in Taiwan Mandarin (Chen et al., 2015). Moreover, data for Catalan reported elsewhere (Recasens & Espinosa, 2009) suggest that [o, u] could be less resistant than [a] perhaps since the formation of a velar or upper pharyngeal constriction for high or mid back rounded vowels constrains the front dorsum to a lesser extent than the formation of a lower pharyngeal constriction for low vowels, mostly so when [a] is especially front.

(b) Regarding the role of consonant manner of articulation, several issues related to coarticulation resistance and aggressiveness deserve to be looked into. In particular, the fricative [s] and trill [r] are expected to be more resistant and aggressive than [ð, l, ɾ, t,n] among dentoalveolars, and the same would hold for the fricative [ʃ] than for [ʎ, ɲ] among palatals. Moreover, we will also look into whether an increase in degree of constraint for [s, r] renders these consonants equally resistant as [ʎ, ɲ, ʃ] and if trilling and frication have as much of an impact on contextual effects at the back of the vocal tract as they do at the tongue front and dorsum. Regarding dentoalveolars of other manners of articulation, the approximant [ð] should be the least resistant of all consonants, which probably

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