Contrast enhancement and cue trading in Irish consonant articulations

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Background: Irish makes wide use of contrastive secondary dorsal articulations, opposing phonemic palatalization /Cʲ/ and velarization /Cˠ/, e.g. /bˠɔːnˠ/ 'white' vs. /bʲɔːnˠ/ 'peak' (e.g. Ó Siadhail 1991, Ní Chasaide 1995). Lip rounding has been reported as a correlate of the /Cʲ Cˠ/ contrast in Irish (e.g. Ó Siadhail 1991), presumably because both lip rounding and tongue body backing affect F2 in consonant-vowel transitions (Stevens 2000). Lip rounding may therefore serve as an ENHANCEMENT GESTURE for /Cʲ Cˠ/ contrasts, exaggerating F2 differences associated with the primary lingual distinction between /Cʲ/ and /Cˠ/ (Stevens & Keyser 1989).

Contrast enhancement may also arise for coronal consonants. Secondary velarization is weak for coronals in Irish (e.g. Mhac an Fhailigh 1980), possibly because coupling between the tongue tip/blade and the dorsum inhibits tongue body backing (e.g. Recasens 1999). The relative weakness of velarization in coronals may lessen the saliency of /Cʲ Cˠ/ contrasts. On the other hand, these contrasts are supported by secondary acoustic cues in the turbulent noise for fricative closure or stop release on palatalized /tʲ dʲ sʲ/ (see below). It is thus possible that speakers compensate for weakened velarization by strengthening noise cues to the /Cʲ Cˠ/ contrast for coronals.

We ask: (i) are secondary /Cʲ Cˠ/ articulations in Irish really enhanced by additional gestures or cues?; (ii) if so, are there TRADING RELATIONS between gestures on a token-by-token basis (e.g. more lip rounding when velarization is weak, in order to achieve consistently low F2)? These questions have implications for theories of contrast enhancement: token-by-token covariation of gestures would suggest that enhancement occurs at the level of surface phonetics (Perkell et al. 2000, Niziolek et al. 2015), while lack of such covariation would suggest that enhancement occurs at a more abstract ('phonological') level (Keyser & Stevens 2006, Stevens & Keyser 2010).

The study: We report results from 5 native speakers of Conamara Irish. Target consonants were palatalized and velarized /p t k f s x/, in words beginning /#Ciː/, /#Cuː/. Dorsal position was recorded with a portable ultrasound machine (57-60 fps), traced at C offset, and analyzed via principal component analysis of tongue shape (Slud et al. 2002). The first principal component (PC1; Fig. 1) seems to correspond to tongue body backness, and accounts for 40.4% of the variance in our data. PC1 values–our measure of tongue body position–indicate that velarized /Cˠ/ are consistently backed relative to palatalized /Cʲ/. Lip rounding was recorded simultaneously with a camcorder; our measure of rounding was SIDE CONTACT, the proportion of upper and lower lips touching when viewed head-on (Goldstein 1991). Audio was recorded with a headset microphone.

Lip rounding: We fit a linear-mixed effect model predicting lip rounding (= side contact) for each token. `Token Backness`, i.e. the PC1 score for each token, should correlate with lip rounding if contrast enhancement occurs on a token-by-token basis. Phonemic `Secondary Articulation` should correlate with lip rounding under either token-by-token ('phonetic') or category-level ('phonological') enhancement. We also included control predictors for `C Place`, `Manner`, `Vowel Context`; all two-way interactions between these factors; several three-way interactions; and by-speaker random slopes for all 5 simple factors. Step-down model simplification resulted in a final model with fewer effects; Table 1 reports statistics for only those simple effects which reached significance. Velarized consonants show more overall lip rounding than palatalized consonants; this effect of

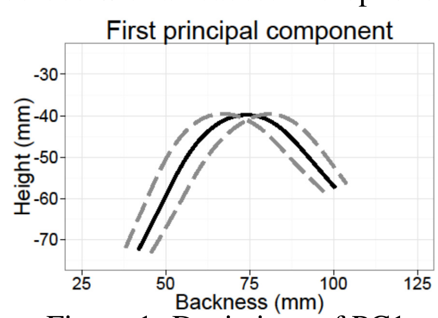

Figure 1: Deviations of PC1

the categorical predictor `Secondary Articulation` was strongest for dorsals and weakest for coronals (Fig. 2). However, there was **no token-level, gradient correlation** between the magnitude of dorsal articulations and the amount of lip rounding (i.e. `Token Backness` did not reach significance). This suggests that lip rounding enhances secondary dorsal contrasts only at a relatively abstract ('phonological') level, and not at the level of individual productions.

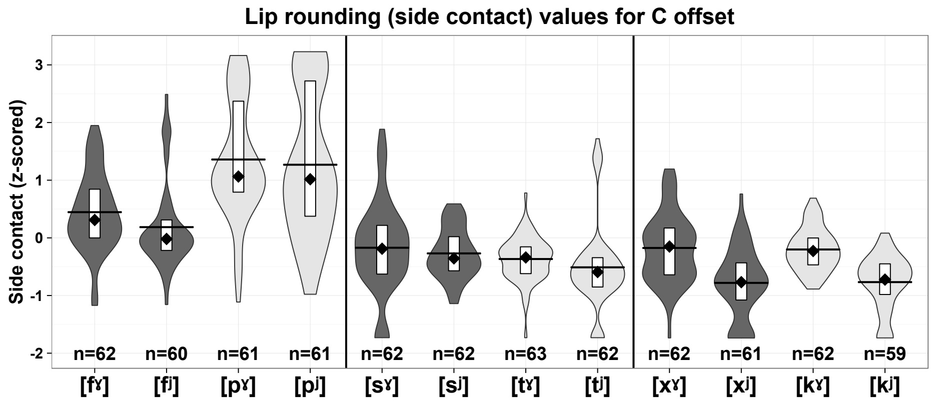

Figure 2: Side contact results

Coronals: Palatalized coronal stops are realized with longer releases than velarized coronal stops (Δ_μ=16ms) in our data. Coronal /Cʲ/ and /Cˠ/ also show a wide separation for the center of gravity (COG) of their noise components (Δ_μ=900-1200Hz). This confirms that coronal /Cʲ Cˠ/ contrasts are realized with robust secondary cues (Ní Chiosáin & Padgett 2012). To assess whether weak velarization on coronal /Cˠ/ is compensated by strengthening secondary acoustic cues on coronal /Cʲ/, we checked whether individual speakers showed a correlation between the average degree of velarization for /sˠ tˠ/ and the difference in average COG between palatalized /sʲ tʲ/ and velarized /sˠ tˠ/. However, no significant correlation was observed ($r = 0.11$). We thus found no evidence for quantitative trading between velarization on coronal /Cˠ/ and acoustic separation of noise cues on coronal /Cʲ Cˠ/. This could suggest that no such relation exists; alternatively, this null result may reflect our small sample size (n = 5 speakers).

	β	$p <$
`C Place` (coronal)	-0.30	.001*
`C Place` (dorsal)	-0.46	.001*
`Sec. Artic.` (/Cʲ/)	-0.09	.05*
`Manner` (fricative)	-0.11	.001*
`V Context` (/#Ci:/)	-0.20	.001*

Table 1: Model statistics

Conclusion: /Cʲ Cˠ/ contrasts are enhanced by lip rounding in Irish, but only at a relatively abstract level. Consistent with this claim, we found no evidence that biomechanically weak velarization on coronal /Cˠ/ is compensated by strengthening secondary cues on coronal /Cʲ/.

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