Contrast enhancement and cue trading in Irish consonant articulations

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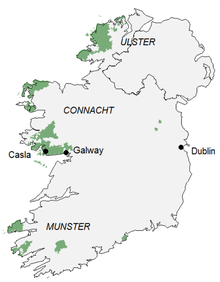
Irish



- **Irish** (or 'Gaelic') is spoken daily by ~70,000-150,000 people in Ireland.
- These speakers are concentrated in *Gaeltachtaí* (Irish-speaking communities) mostly found on the western coast.
- Irish is **at risk of marginalization** even in traditional Irish-speaking communities (Ó Giollagáin & Charlton 2015).
- Still, a much larger proportion of the Irish population reports some fluency in the language.
- Our focus here: **Connemara Irish**, spoken in the western Gaeltacht region.

Secondary articulations in Irish

All consonants in Connemara Irish are contrastively **velarized or palatalized** (Ní Chasaide 1995).

	Labial	Coronal	Dorsal	Glottal
Stops	p^{γ} p^{j} b^{γ} b^{j}	t^{γ} t^{j} d^{γ} d^{j}	k^{γ} k^{j} g^{γ} g^{j}	
Fricatives	f^{γ} f^{j} v^{γ} v^{j}	s^{γ} s^{j}	x^{γ} x^{j} (γ^{γ} γ^{j})	h^{γ} (h^{j})
Nasals	m^{γ} m^{j}	n^{γ} n^{j}	$ŋ^{\gamma}$ $ŋ^{j}$	
Liquids		l^{γ} l^{j} r^{γ} r^{j}		

- Our study: the production of /C^{γ} C^{j}/ for **word-initial voiceless obstruents** in **different vowel contexts**.

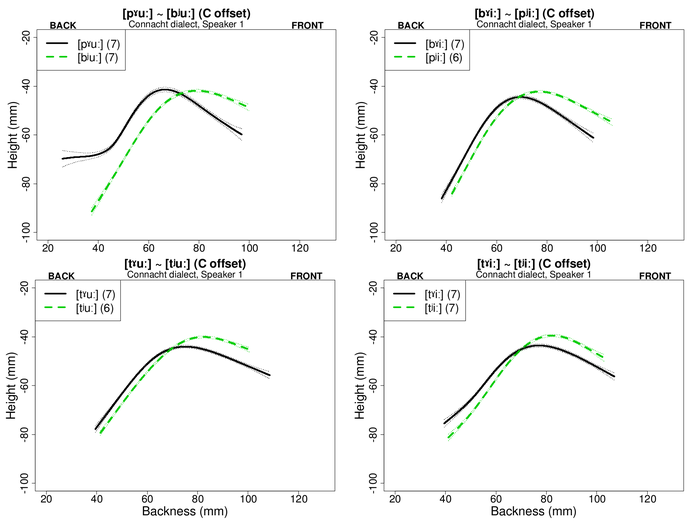
  (1) a. *tuí* [t^{γ}i:] 'straw'
  b. *tí* [t^{j}i:] 'house (GEN)'

- (/b^{γ} b^{j}/ used to fill lexical gaps for /p^{γ} p^{j}/)
- Secondary palatalization contrasts are **undergoing attrition** for younger speakers, even in Irish-speaking communities. (Ó Béarra 2007, Ó Curnáin 2007, Péterváry et al. 2014).

The phonetics of /C^{γ} C^{j}/ in Irish

In Connemara Irish, /C^{γ} C^{j}/ contrast is **consistently realized as a difference in tongue body backing** (Bennett et al. 2018).

- **Major acoustic correlate**: **F2** at [CV] and [VC] transitions (e.g. Ní Chiosáin & Padgett 2012).
- Little evidence of [CV] coarticulation, or other articulatory variation across vowel contexts.



Secondary **velarization weakest for coronals** (e.g. Mhac an Fhailigh 1980).

- **Coupling** between tongue tip/blade and dorsum **may inhibit backing** (e.g. Recasens 1999).

Traditional descriptions report a **correlation between secondary lingual articulations and lip rounding** (e.g. Ó Siadhail 1991).

- /C^{γ}/ ⇔ more rounding
- /C^{j}/ ⇔ less rounding (or even active spreading)

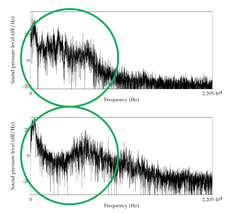
Contrast enhancement and stability

Lip rounding and dorsum backing **both affect F2 at [CV]/[VC] transitions** (e.g. Stevens 2000).

- Lip rounding may be an **enhancement gesture** for /C^{γ} C^{j}/ contrasts, **exaggerating F2 differences** associated with primary lingual distinctions (Stevens & Keyser 1989).

Contrast enhancement may also occur with coronal consonants.

- Secondary velarization **/C^{γ}/ relatively weak for coronals**.
- **But**: coronal /C^{γ} C^{j}/ contrasts are supported by **robust secondary acoustic cues in constriction noise** (fricative closure and stop release) (e.g. Ní Chiosáin & Padgett 2012).
  - Spectral shape (e.g. center of gravity)
  - Duration
- Perhaps velarization (≈F2) and secondary noise cues **trade-off in strength**?



Research questions

Lip rounding:

1. Are secondary lingual articulations /C^{γ} C^{j}/ in Irish **enhanced by additional gestures/cues**?
2. 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)

Implications for theories of contrast enhancement:

- **Token-by-token covariation of gestures** ⇒ enhancement occurs at a *surface phonetic level* (e.g. Perkell et al. 2000, Niziolek et al. 2015)
- **No token-by-token covariation** ⇒ enhancement occurs at a *more abstract ('phonological') level* (e.g. Keyser & Stevens 2006, Stevens & Keyser 2010).
  - E.g. presence/absence of supplementary rounding gesture specified for a given segment, but not *strength* of that gesture.

Coronal velarization:

- **Hypothesis**: speakers with weaker velarization on coronal /C^{γ}/ will compensate by exaggerating secondary noise cues to /C^{γ} C^{j}/ contrast.

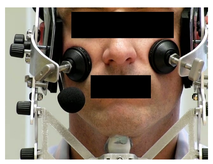
The study

Speakers: 5 native speakers of Connemara Irish, working as professional Irish-language radio broadcasters (Bennett et al. 2018).

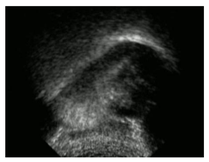
Materials: wordlist (24 items)

- Word form: [#CV. . .] (1-2 syllables), where V∈/i: u:/.
- Velarized /C^{γ}/ and palatalized /C^{j}/ voiceless obstruents (=/p~b t k f s x/).

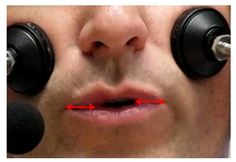
Data acquisition: portable ultrasound and video recorder (head-on view of lips)



Stabilization headset (with microphone)

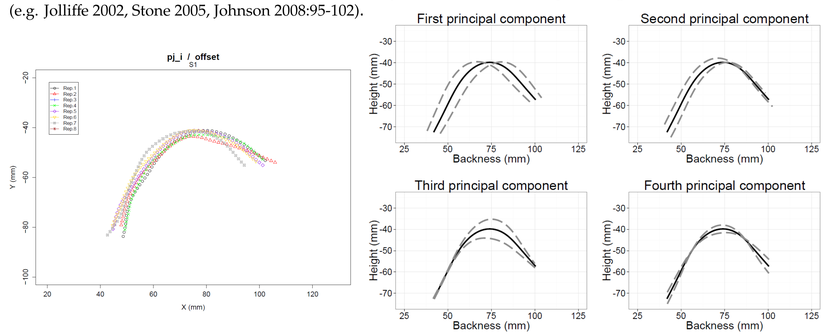


Raw image (57-60 fps) (traced at C offset)



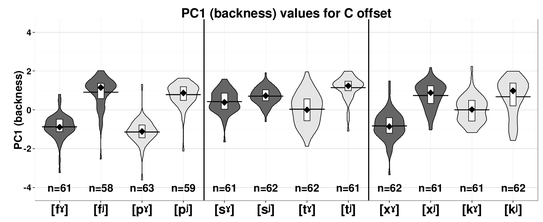
Lip rounding (side contact) (Goldstein 1991, Kavitskaya & Barnes 2003)

Statistical method: principal component analysis (PCA) over tongue shape (e.g. Jolliffe 2002, Stone 2005, Johnson 2008:95-102).



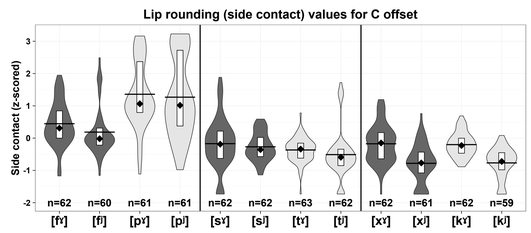
Results: lingual ultrasound

First principal component (PC1; 40.4% of variance) corresponds to **tongue body backness**.



- **PC1 consistently distinguishes /C^{γ} C^{j}/** across place, manner, and vowel context.
- PC1 confirms that **velarization is weakest for coronals**.
  (all interpretations supported by linear mixed-effects modeling; Bennett et al. 2018).

Results: lip rounding



Lip rounding (=side contact) predicted with linear-mixed effects modeling:

- Lip rounding and PC1 averaged over {place, manner, secondary articulation, vowel context, speaker} to reduce noise from measurement error (n=120 data points).
- Five fixed-effects predictors and all two-way interactions
- Random intercepts and by-speaker random slopes for all 5 simple factors

Fixed effect	Comment	Significant under:
TOKEN BACKNESS	PC1 score for each token	'Phonetic' enhancement
SECONDARY ARTICULATION	/C^{γ}/ vs. /C^{j}/	Either account
C PLACE	Control	—
C MANNER	Control	—
V CONTEXT	Control	—

Simplified model (some interactions omitted)	β	$p <$
SEC. ARTIC. (/C^{j}/)	-0.13	.005*
C PLACE (coronal)	-0.30	.001*
C PLACE (dorsal)	-0.53	.001*
MANNER (fricative)	-0.15	.01*
V CONTEXT (/#Ci:/)	-0.17	.001*
C PLACE : SEC. ART. (coronal : /C^{j}/)	0.08	.15
C PLACE : SEC. ART. (dorsal : /C^{j}/)	-0.15	.005*

- **Velarized consonants show greater lip rounding** than palatalized consonants. (Especially dorsals and /f^{γ}/).
- **No token-level, gradient correlation** between the magnitude of lingual articulations and the amount of lip rounding (i.e. TOKEN BACKNESS did not reach significance).
- Appears that **lip rounding enhances secondary lingual contrasts only at a relatively abstract ('phonological') level**, and not at the level of individual productions.

Results: coronal velarization

/s^{γ}/ : /s^{j}/ and /t^{γ}/ : /t^{j}/ have **widely separated centers of gravity** (COG; Δ_{μ}=900-1200Hz)

- Confirms that **coronal /C^{j} C^{γ}/ contrasts are realized with robust secondary cues**.

But do individual speakers show a correlation between:

- Average degree of velarization for /s^{γ} t^{γ}/, and
- *difference* in average COG between /s^{γ} s^{j}/ and /t^{γ} t^{j}/?

No evidence for quantitative trading between velarization on coronal /C^{γ}/ and acoustic separation of noise cues on coronal /C^{γ} C^{j}/ (r=0.11, *n.s.*; n=5).

- Could indicate that no such trading relation exists.
- This null result may also reflect our small sample size (5 speakers/data points).

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REFERENCES Available by email on request.

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