

# Phonological Effects on Vowel Coarticulation and Variability

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Adaptive Dispersion Theory (ADT; Lindblom 1986) and articulatory output constraints (Manuel 1990) make overall predictions about inventory size and its relationship to vowel spacing and variability. In a comparative study of Romanian and Italian vowels, this paper finds phonologically-determined patterns in coarticulation that can be separated from articulatory variability. Rates of coarticulation differ systematically across coarticulatory contexts and target vowel types within each language. While Romanian appears to have greater overall variability than Standard Italian, it in fact exhibits systematically increased coarticulation in contexts that parallel assimilatory phonological alternations. These results demonstrate the necessity of separating systematic variation from random variability to understand sources of variation in vowel systems.

Lindblom and colleagues predict that a vowel system maximally fills the available acoustic space by occupying its periphery before the interior. Romanian and Italian each have seven monophthongs in their phonemic vowel systems (Table 1), so we predict similar amounts of coarticulation and variability in their vowel spaces. Both languages have five peripheral vowels, but Romanian has two central vowels (/i, ʌ/) while Standard Italian has two additional peripheral low-mid vowels (/ɛ, ɔ/). Additionally Romanian (but not Standard Italian) exhibits two contextually-governed phonological alternations among stressed vowels: metaphony, in which the quality of a word-final vowel conditions the height of the preceding stressed vowel; and centralization of front vowels following a labial consonant.

**Table 1.** Phonemic vowels of Italian and Romanian

Italian		Romanian		
/i/	/u/	/i/	/i/	/u/
/e/	/o/	/e/	/ʌ/	/o/
/ɛ/	/ɔ/		/a/	
	/a/			

These similarities and differences provide an interesting point of comparison for an acoustic study of Italian and Romanian phonemic vowels, measuring magnitudes of coarticulation to investigate the potential presence of phonetic parallels to phonological alternations. Eight Italian and nine Romanian speakers participated. The stimuli included trisyllabic nonce words of the form /kV<sub>1</sub>.C<sub>2</sub>V<sub>2</sub>.C<sub>3</sub>V<sub>3</sub>/ in which vowels and consonants varied systematically flanking a stressed target vowel, as in (1); for example, /ki'papi/, in Romanian *chipapii* and Italian *chipapi*. This methodology, which allows comparison and statistical modeling of coarticulation in both carryover and anticipatory contexts, produced 80 Italian stimuli and 144 Romanian stimuli. Formant values (F1 and F2) were measured at the midpoint of the stressed target vowel (V<sub>2</sub>), and were compared across the cross-balanced consonantal, vocalic, and target vowel contexts.

$$(1) \text{ Italian: } /k \left\{ \begin{matrix} i \\ a \end{matrix} \right\} \left\{ \begin{matrix} p \\ tʃ \end{matrix} \right\} \mathbf{V}_2 \left\{ \begin{matrix} p \\ tʃ \end{matrix} \right\} \left\{ \begin{matrix} i \\ a \end{matrix} \right\} / \quad \text{Romanian: } /k \left\{ \begin{matrix} i \\ a \end{matrix} \right\} \left\{ \begin{matrix} p \\ ts \end{matrix} \right\} \mathbf{V}_2 \left\{ \begin{matrix} p \\ ts \end{matrix} \right\} \left\{ \begin{matrix} i \\ a \end{matrix} \right\} /$$

If vowel inventory size alone is responsible for coarticulation and variability, we hypothesize similar patterns in Romanian and Italian. However, we find interesting and systematic differences. Italian data points are tightly clustered and exhibit substantial separation among vowel types, while Romanian shows overlap in the vowel space, particularly among central vowels, and it has a slightly larger acoustic space in the F1 and F2 dimensions. Moreover, magnitudes of coarticulation are not symmetrical: they vary across anticipatory and

carryover contexts, and also across target vowels. This is illustrated for F2 in Tables 2 and 3, which show how the target vowel space is affected by opposing coarticulatory contexts. In Italian, carryover coarticulation rates (both vowel-vowel and consonant-vowel) exceed anticipatory effects, whereas Romanian shows an important asymmetry: anticipatory V-V coarticulation exceeds carryover V-V coarticulation, paralleling the right-to-left directionality of assimilation in metaphony. Coarticulatory effects are consistently of greater magnitude in Romanian than Italian (seen in the darker shading for Romanian in Tables 2 and 3); in Romanian, carryover C-V coarticulation (paralleling post-labial vowel centralization) produces the largest effects, with mean F2 differences of nearly 300 Hz across contexts. These effects remain significant when data is normalized across speakers. However, since coarticulatory effects are not consistent across target vowels (seen in the different shades across vowels in Tables 2 and 3), statistical mixed modeling finds that different coarticulatory parameters are significant for each vowel and formant.

**Table 2.** Difference in mean F2 across vowel-vowel coarticulatory contexts (/a/ vs. /i/)

Vocalic Effects on V <sub>2</sub> – Romanian			Vocalic Effects on V <sub>2</sub> – Italian			Difference in F2
V <sub>1</sub> --> V <sub>2</sub>		V <sub>2</sub> <-- V <sub>3</sub>	V <sub>1</sub> --> V <sub>2</sub>		V <sub>2</sub> <-- V <sub>3</sub>	
i	ɨ	u	i	ɨ	u	< 25 Hz
e	Λ	o	e	Λ	o	26-50 Hz
	a			a		51-150 Hz
						151-200 Hz

**Table 3.** Difference in mean F2 across consonant-vowel coarticulatory contexts (/p/ vs. /ts, tʃ/)

Consonantal Effects on V <sub>2</sub> – Romanian			Consonantal Effects on V <sub>2</sub> – Italian			Difference in F2
C <sub>2</sub> --> V <sub>2</sub>		V <sub>2</sub> <-- C <sub>3</sub>	C <sub>2</sub> --> V <sub>2</sub>		V <sub>2</sub> <-- C <sub>3</sub>	
i	ɨ	u	i	ɨ	u	< 25 Hz
e	Λ	o	e	Λ	o	26-50 Hz
	a			a		51-150 Hz
						151-200 Hz
						> 200 Hz

Given the overall phonological similarity of the languages, these differences are likely related to the presence in Romanian, and lack in Italian, of synchronic phonological alternations based in assimilation. At first glance, the results suggest that Romanian has greater phonetic variability (in addition to more coarticulation) than Italian. However, in a subset of the data in which coarticulatory contexts are held constant, we find that the tightly-clustered Italian data points have greater standard deviations of F1 and F2 than the heavily coarticulated Romanian vowels. Thus while Romanian vowels appear more variable, their realization is in fact linked to coarticulatory context more tightly than Italian vowels are. This requires a more nuanced analysis than suggested by Manuel (1990), indicating three things: First, phonological alternations are relevant for determining rates of coarticulation. Second, in order to model the sources of variability in the vowel space, we must tease apart systematic coarticulatory variation from random articulatory variability. Finally, coarticulatory forces do not apply evenly across a vowel system; vowels are subject to widely varying amounts of coarticulation. Thus a single parameter of vowel inventory size is insufficient to account for the patterns of variability found in these two languages. A remaining open question is the causal link between the phonetic and phonological processes in Romanian.

## References

- Lindblom, B. 1986. Phonetic universals in vowel systems. In John J. Ohala & Jeri J. Jaeger (eds.), *Experimental phonology*, 13–44. Orlando, Florida: Academic Press.
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