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Coarticulation vs Phonologization: Evidence from Southern Italo-Romance

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Abstract: This study compares the variety of Italian spoken in Campania and the Italo-Romance variety of Mormanno (Calabria) to investigate the acoustic differences between phonetic vowel-to-vowel coarticulation and phonologized metaphony. The study analyzed time-varying F1 trajectories and quantified mutual information between stem and suffix vowels. While coarticulation was temporally localized in Campanian Italian, Mormanno showed a phonologized pattern in which the suffix influence extended from stem onset to offset. Despite this stronger influence, there was reduced mutual information and reduced suffix distinctiveness in Mormanno. These findings indicate that sound change involves decoupling acoustic cues from coarticulatory sources, signaling a transition from phonetic variation to phonological change.

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1. Introduction

Coarticulation,[1–3] in which speech sounds overlap with and influence each other in time, is ubiquitous in language. This type of context-dependent variation can result in phonologization, i.e., cue transfer-based sound change,[4,5] in which coarticulation becomes contrastive, i.e., forms the basis of new lexical distinctions. Examples of phonologization-based sound changes are the following. In tonogenesis, differences in fundamental frequency at acoustic vowel onset, which are conditioned by voicing properties of the preceding obstruent, lead to the development of lexical tones, e.g., /da, ta/→/tà, tá/, with contrastive low/high tones, respectively.[6] Similarly, in the development of contrastive vowel nasalization, nasal consonants are weakened and deleted as the cues to nasalization are transferred to the preceding vowel.[6,7] (e.g., Latin SONUS → French 'son', Portuguese, 'som': /sõ/, *sound*).

These types of sound changes can take place over several decades, thereby making them hard to track with modern empirical techniques. The proposed solution to this problem in the present study and others[8–10] is to compare closely related varieties that are spoken today but differ in whether or not phonologization has taken place. An analysis of their differences can then be used to determine the phonetic conditions that might cause the "conservative" variety (in which there is no sound change but only coarticulation) to turn into the "innovative" variety (in which sound change has, or has begun to, take hold).

The type of phonologization analyzed in this study is metaphony[11] found in many Italo-Romance varieties whose phonetic origins are hypothesized to lie in V_1CV_2 trans-consonantal vowel coarticulation.[12] The "conservative," i.e., non-metaphonizing, variety under examination is Italian as spoken in the Campania region of Southern Italy (Campanian Italian, henceforth, CI), which is geographically proximate to Mormanno (MM; our other test case). Campanian speakers are known to have both metaphony and final vowel weakening in their local native Italo-Romance variety (e.g., Neapolitan).[13,14] Yet, to our knowledge, there is no evidence that VCV coarticulation is evolving, or has evolved, into a metaphonic sound change when Campanians speak their regionally colored Italian.

The analyzed "innovative," i.e., metaphonizing variety (in which metaphony has taken hold[15]) is spoken in the village of MM located on the northwest edge of Calabria, in Southern Italy. Metaphony in MM (and in many other Italo-Romance varieties) is manifested as stressed vowel height raising (or, alternatively diphthongization, in which the raising mainly affects the first half of the vowel duration) in the V_1 stem in the context of a high vowel suffix, suffix-/i, u/.[11,12,15,16] Thus, whereas there are no perceptible stem vowel differences in CI [vɛrde, vɛrdi]/('green', sing. vs pl.) or [nɔme, nɔmi]/[17] ("noun"/"nouns"), the stems of these pairs in MM are different because there is a raised vowel before high-vowel suffixes: thus, [vɛrde, v**e**rdi] and [nɔme, n**o**mi].

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Table 1. The number of unique stem and suffix vowel combinations in the two varieties.

		CI		MM		
Stem vowel	Suffix vowel	*n*	Example	*n*	Example	Total
/e/	/e/	25	*mette* (s/he puts)	11	*mese* (month)	36
	/i/	25	*metti* (you put)	12	*mesi* (months)	37
/o/	/e/	19	*nome* (noun)	10	*ponte* (bridge)	29
	/i/	27	*nomi* (nouns)	14	*ponti* (bridges)	41
Total		96		47		143

The analyses of CI and MM are guided by three predictions that distinguish gradient coarticulation from phonologized sound change. First, coarticulation is, typically, temporally localized and highly variable, with the strongest effects occurring near the boundary between adjacent segments.[18,19] If the stem vowel V_1 is affected by phonologized sound change rather than gradient coarticulation, then the influence of the suffix vowel (V_2) should extend across the entire duration of V_1, or at least over a greater temporal extent than in the coarticulation case. Second, models of sound change based on cue transfer predict that, as a coarticulatory effect becomes contrastive and phonologized, the coarticulatory source that gives rise to it may be reduced and even deleted. This is illustrated by the development of contrastive vowel nasalization in French: As anticipatory nasalization on the vowel became phonologized, the nasal consonant in VN sequences was progressively weakened and eventually deleted. Applied to metaphony, the analogous prediction is that, as also observed elsewhere in Italo-Romance,[20] the acoustic contrast between suffix vowels (e.g., -/i/ vs -/e/) should be weaker in a variety like MM, in which metaphony has taken hold, than in CI, in which variation in the stem vowel may be conditioned only by coarticulation. Third, if the progression of sound change weakens coarticulatory coupling,[21] then the degree to which V_1 covaries with V_2 should be reduced in MM compared with CI. Taken together, these three predictions allow us to assess whether variations due to vowel-to-vowel coarticulation and metaphony are phonetically distinct and whether the former can plausibly serve as the basis for the latter.

Section 2 is a test of whether coarticulation is temporally more extensive (prediction 1) and whether the suffix is reduced to a greater extent (prediction 2) in MM compared with CI. The lesser degree of covariation between the stem and suffix in MM (prediction 3) is tested in Sec. 3.

2. Coarticulation and reduction in stem and suffix vowels

2.1 Method

The participants included 28 MM speakers (age range 15–81 years, median age 44 years, 15 female) born and raised in the village of MM and 15 CI speakers (age range 19–40 years, median age 33 years, 6 female) born and raised in the Italian region of Campania. None of the speakers reported any speech or hearing impairments.

The materials included words containing $V_1C_nV_2$ final sequences, in which V_1 was a mid-front or a mid-back /e, o/[22–24] vowel in a lexically stressed syllable, C_n consisted of one (singleton or geminate) or two consonants, and V_2 was an inflectional suffix vowel-/e, i/ marking person in verbs or number in nouns and adjectives (Table 1). These vowels occurred in 143 different target words that were all disyllabic in CI; in MM, 41 were disyllabic and 6 trisyllabic (e.g., *nipote/i*, "nephew," sing./plural). The 143 target words were constituted from 113 unique stems (CI, $n=62$; MM, $n=51$), of which 44 (CI, $n=35$; MM, $n=11$) were suffix-paired (e.g., *nome* and *nomi*, as in Table 1). Except for one case (*bon-*, "good"), the unique stems in CI were different from those in MM (e.g., stem *mes-*, "month" occurred in the MM but not in the CI data).

MM speakers were recorded in a quiet environment in their homes. They produced the target words from a computer monitor in a randomized picture-naming task. The target words were produced both in isolation and in a carrier sentence with nuclear accent on the target word. Each MM speaker typically produced between one and two repetitions per target word across these conditions. The CI speakers were recorded in the laboratory. They also produced from a computer monitor three repetitions of each target word embedded in a carrier sentence or in isolation in nuclear accented position. The total number of acoustically analyzed target words in the present study was 12 213 (MM, $n=3623$; CI, $n=8590$).

The speech data were segmented and labeled using a first-step of forced alignment followed by manual correction. The first formant frequency (F1) which was used to index phonetic vowel height was extracted using the PRAATR package[25] in R[26] with a 25 ms Hamming window and a 5 ms frame shift. F1 was *z*-score normalized[27] with reference to each speaker's /i, u, a/ that had been separately produced in lexically stressed syllables. The F1 data were linearly time-normalized to 11 equidistant time points between the acoustic onset and offset separately for all stem and suffix vowels.

The stem and suffix vowels were analyzed separately with generalized additive mixed models (GAMMs). Time-varying F1 was the dependent variable of interest. The data across the stem vowels /e, o/ were pooled, given that there were only minimal F1 differences between them. In addition, a random smooth by item was included to capture residual differences between the two stem vowels.

The fixed factor in the GAMM was formed from a combination of the variety and suffix (four levels: MM, CI × suffix-/e, i/). Factor smooths were included to model the non-linear differences between speakers and between stems over time.

For the suffix vowels, the portion between proportional time 0.75 and vowel offset was excluded from further analysis in order to reduce the influence of following consonants (for productions under the carrier sentence condition) and potential formant-tracking errors associated with transitions into regions of silence (for productions in isolation).

All analysis scripts and data are available at https://osf.io/nyz9k/overview?view_only=4a7496d3d686440fa3f430fe03a9c841.

2.2 Results

Figure 1 shows the 95% confidence intervals of the F1 trajectories of stem vowels as predicted by the GAMM for the two varieties in the context of the suffix vowels-/e/ and -/i/. In MM, the trajectories are separated throughout most of the vowel duration (red for suffix-/e/, blue for suffix-/i/). In contrast, in CI they are separated only at the end of the vowel, consistent with a phonologized metaphonic effect in the former case and phonetic V-to-V coarticulation in the latter.

The statistical results from the GAMM align with this interpretation: The suffix vowel exerted a significant influence across the entire duration of the stem vowel in MM, but only toward the vowel offset in CI (between normalized time $t = 0.56$ and 1).

Turning to the suffix vowels, Fig. 2 shows that the F1 trajectories for -/e/ and -/i/ in MM are much closer than in CI (see top left vs top right panels[28]). These findings suggest that the closer approximation between the suffix vowels in MM arises primarily because suffix-/i/ undergoes stronger raising, and, possibly, centralization (with a concomitant shift toward /e/), than in CI: See Fig. 2, bottom left vs right, comparing the similarity of CI and MM suffix-/e/ vs the difference observed for -/i/.

2.3 Discussion

The results have shown that the cues to the suffix vowel are distributed throughout the stem vowel in MM, whereas in CI they were confined to the second half of the stem vowel. The results also showed that suffix-/i/ was more centralized and closer to suffix-/e/ in MM than in CI. Both findings are consistent with a diminished anticipatory vowel-to-vowel coarticulation and phonologization of suffix effects on the stem vowel in MM. Section 3 makes use of mutual information to test this hypothesis of a weaker coarticulatory influence of the suffix on the stem vowel in MM than in CI.

3. Degree of covariation between stem and suffix vowels

3.1 Method

Mutual information (MI) captures statistical dependence between two variables without assuming linearity, making it appropriate for detecting coarticulatory influence regardless of its functional form.[1,29] MI was computed using the function getMI(),[30] an R implementation of the histogram-based estimator, following the approach of Iskarous *et al.*[1] and

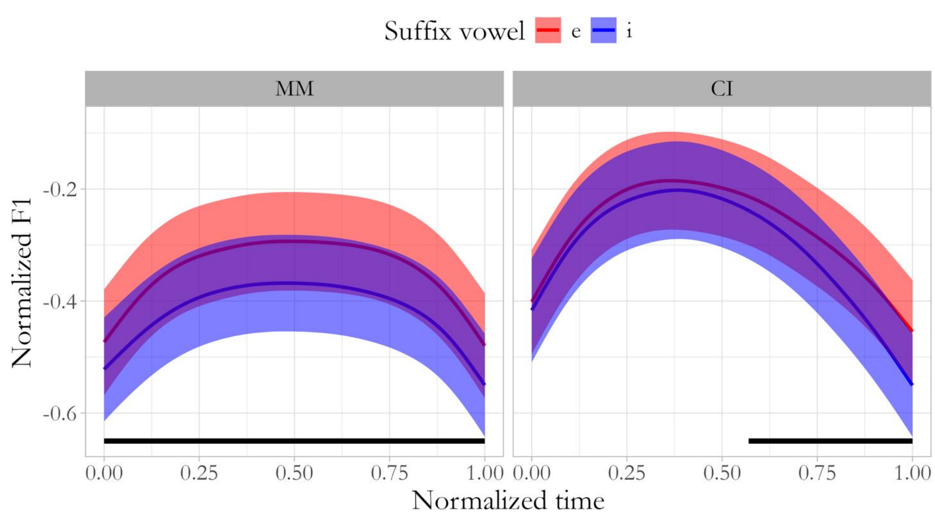

Fig. 1. The 95% confidence intervals predicted by the GAMM for F1 in the stem vowel shown separately for variety and suffix vowel combinations. The black lines denote the time interval over which the differences due to suffix-/e, i/ were statistically significant.

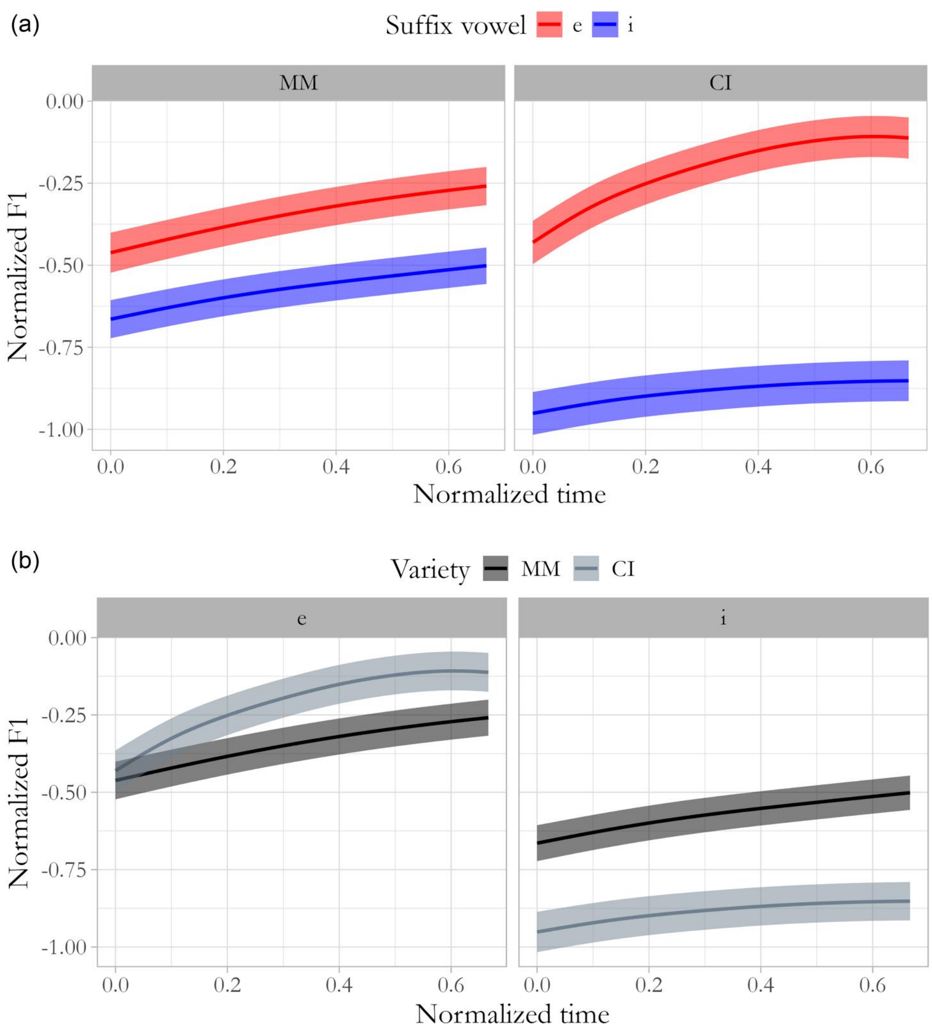

Fig. 2. The 95% confidence intervals predicted by the GAMM for F1 in the suffix vowel shown separately for variety and suffix vowel combinations displayed by variety (a) vs by suffix vowel quality (b).

previously employed by Burroni and Tilsen.[29] For each repetition separately, MI was measured between F1 in the suffix vowel at its temporal midpoint and F1 of each of five time points equally spaced from the onset to the offset of the stem vowel, yielding five MI measurements per token. The joint distribution of stem and suffix F1 values was approximated via a two-dimensional histogram with 20 equally spaced bins per dimension, with bin edges spanning the observed range of each variable.[31] Laplace smoothing (additive constant = 0.5, following Jeffrey–Perks law) was applied to the joint histogram counts prior to normalization; marginal distributions were derived from the smoothed joint distribution. MI was expressed in bits:

$$MI(\mathrm{F1_{STEM}};\mathrm{F1_{SUFFIX}}) = \sum_{\mathrm{F1_{STEM}}}\sum_{\mathrm{F1_{SUFFIX}}} p(\mathrm{F1_{STEM}};\mathrm{F1_{SUFFIX}})\log_2\frac{p(\mathrm{F1_{STEM}};\mathrm{F1_{SUFFIX}})}{p(\mathrm{F1_{STEM}})p(\mathrm{F1_{SUFFIX}})}.$$

This yielded a time-varying MI profile across the stem for each speaker. MI values were subsequently averaged across all five time points for each speaker and suffix vowel condition and entered in a mixed-effects analysis of variance using *aov_4*() from the *afex* package in R, with variety as a between-speakers factor, suffix vowel as a within-speakers factor, and speaker as the random effect.

All analysis scripts and data are available at https://osf.io/nyz9k/overview?view_only=4a7496d3d686440fa3f430fe03a9c841.

3.2 Results

Figure 3(a) shows the MI between the stem and suffix vowel by variety, speaker, and suffix vowel. In all cases, MI scores were calculated separately between F1 at the suffix vowel's temporal midpoint and F1 at each of five equally spaced time points between stem vowel onset and offset. The figure shows that the MI between the stem and suffix vowels is higher for all time points in CI than in MM. The same figure also suggests that the MI is higher between the stem and suffix-/i/ than between the stem and suffix-/e/. The results of a mixed-effects analysis of variance (ANOVA) showed significant influences of both variety and suffix vowel on MI (variety: ($F[1, 41] = 294.15$, $p < 0.001$; suffix vowel: $F[1, 41] = 39.06$, $p < 0.001$) with no significant interaction between them. These results are consistent with the idea that the coarticulatory dependence between stems and suffixes is weaker in MM compared to CI.

4. General discussion

This study compared two Southern Italo-Romance varieties that were shown to differ in whether suffix-conditioned stem vowel variation reflects gradient, phonetic coarticulation or categorical, phonologized sound change. The results converged on three related findings. In the variety with sound change, MM, the acoustic influence of the suffix vowel was distributed across the entire duration of the stem vowel, whereas in the variety with gradient coarticulation, CI, it was confined to the second half—consistent with a phonologized, temporally extended effect in the former and phonetic, localized anticipatory coarticulation in the latter. At the same time, the acoustic contrast between suffix vowels-/e, i/ was more reduced in MM, with suffix-/i/ showing stronger lowering (most probably in the direction of phonetic centralization) toward /e/ compared with CI. Finally, MI between stem and suffix F1 was lower in MM, suggesting a lower degree

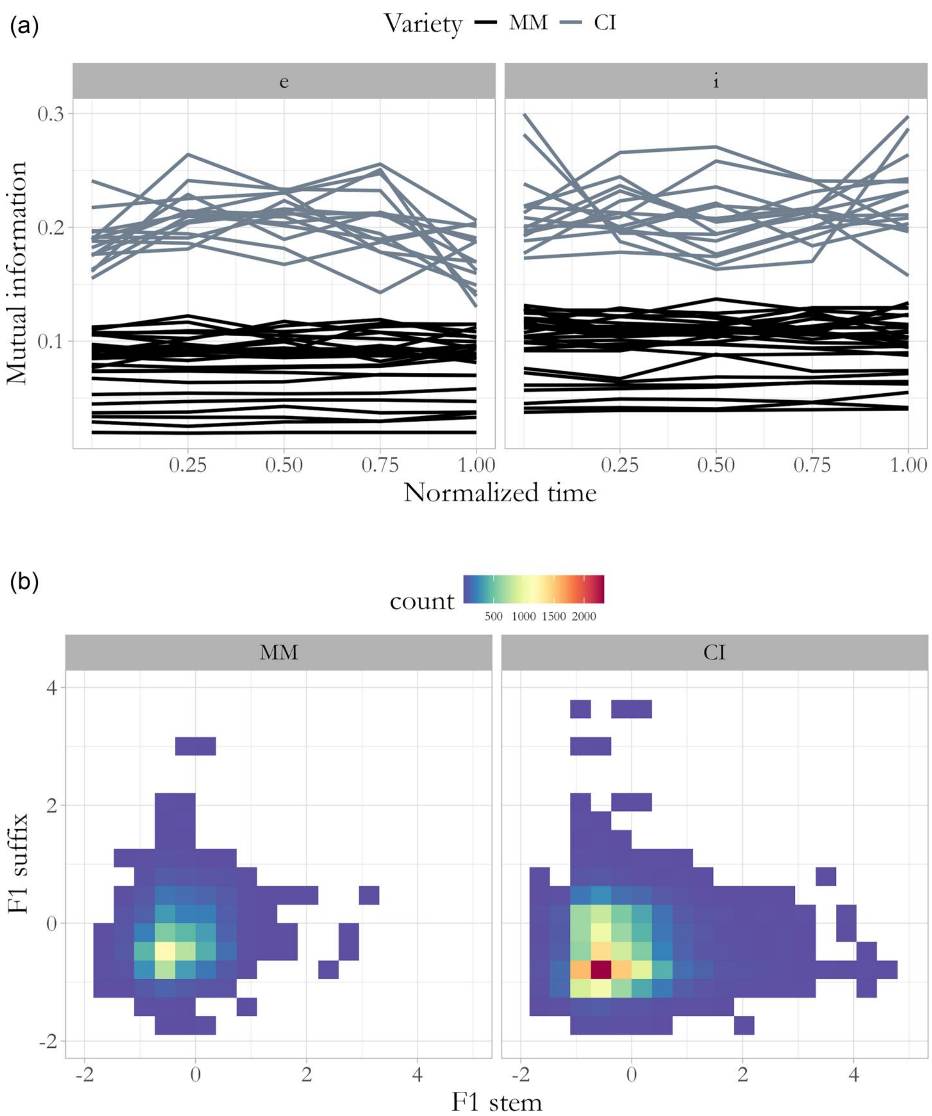

Fig. 3. (Top) Mutual information (MI) in the stem vowel shown separately by suffix vowel-/e, i/ aggregated by speaker in MM (black) and CI (gray). (Bottom) MI is estimated using a 20-bin grid in each of the two dimensions F1 stem and F1 suffix. MI estimated using coarser or finer bin grids is illustrated in the supplementary material.

of coarticulatory dependency, in spite of stronger cues to suffix vowel identity in the stem. Together, these findings point to a dissociation between coarticulatory source and effect that is characteristic of the type of phonologization in MM in which cue transfer is partial, that is, in which the cues to inflectional morphology have not been completely transferred from the suffix to the stem (as they have in other Lausberg varieties; see Ref. 15) but are in evidence in both the stem and suffix. This type of partial cue transfer is found in other types of sound change such as the phonologization of nasalization, in which an oral/nasal contrast is evident in the vowel, even though the final nasal consonant has not been completely deleted (see Ref. 32, pp. 20 and 75–77 for examples from Italian dialects).

The lower MI in MM is a result that requires explanation, since it runs counter to the intuition that a stronger suffix influence on the stem should entail greater statistical dependency between suffix and stem vowels. The resolution lies in the suffix itself: in MM, the acoustic distinction between suffix-/e, i/ has been substantially reduced through centralization, meaning that the stem carries the consequences of a contrast that the suffix encodes less reliably. The coarticulatory source has weakened even as its effect on the stem has strengthened and temporally redistributed. This is precisely the source-effect dissociation predicted by models of cue transfer:[33,34] As a coarticulatory effect becomes contrastive and enters the lexicon, the segment that originally triggered it may be progressively reduced or even deleted—as, for instance, in the development of contrastive vowel nasalization in French, where the nasal consonant was weakened and eventually lost as nasality was transferred to the vowel.[7]

Within the framework of Articulatory Phonology,[35,36] the high MI in CI follows naturally from gestural overlap:[18] when the tongue-dorsum gesture for V_2 extends anticipatorily into V_1, the signal at the offset of V_1 and the nucleus of V_2 are acoustic signatures of the same underlying gesture, yielding a tight and predictable source-effect relationship. Importantly, the magnitude of this coarticulatory influence on V_1 should scale with the size of the acoustic contrast between the suffix vowels—the larger the cue difference at V_2, the more that difference propagates into V_1. This is exactly what CI shows: Robust suffix contrasts paired with a temporally localized but acoustically coherent coarticulatory effect. MM presents the mirror image: The suffix contrast has been reduced, yet its influence on the stem is stronger and more temporally extended, indicating that the effect has become decoupled from its gestural source and is no longer straightforwardly predictable from it.

This decoupling is central to the life-cycle model of sound change,[21,37,38] in which coarticulatory variation—initially automatic and gradient—progressively comes under cognitive and lexical control as it becomes phonological. A complementary account is provided by cue-trading:[33] When one cue to a contrast weakens, listeners may shift their reliance to another cue that is temporally or spectrally distinct from it.[7] Applied to metaphony, the weakening of the acoustic contrast at the suffix vowel is compensated by an enhanced and temporally redistributed cue in the stem. The result is the inverse relationship between source strength and effect strength that characterizes MM and that stands in sharp contrast to the tightly coupled, coarticulation-driven pattern observed in CI.

5. Conclusion

The comparison in this study between two Southern Italo-Romance varieties has provided evidence for the first stages of a sound change where a coarticulatory effect has been decoupled from its original source and transferred anticipatorily. The consequence of this decoupling is to make the coarticulatory source-effect relationship less predictable compared with synchronic variation in the absence of diachronic changes, thus paving the way to sound change.

Supplementary Material

See supplementary material for additional figures and analyses.

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Author Declarations

Conflict of Interest

The authors have no conflicts to disclose.

Ethics Approval

The authors obtained ethical approval from the institutional review boards of LMU Munich. Informed consent was obtained from all participants.

Data Availability

The data that support the findings of this study are openly available in an OSF repository at https://osf.io/nyz9k/overview?view_only=4a7496d3d686440fa3f430fe03a9c841.

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