Andrea Calabrese* and Mirko Grimaldi*

Metaphony in the Tricase Southern Salentino variety: acoustic, articulatory, and phonological analysis

https://doi.org/10.1515/probus-2026-0005
Received April 16, 2026; accepted April 17, 2026; published online June 10, 2026

Abstract: Southern Salentino varieties have a five-vowel system, /i, ɛ, a, ɔ, u/, exhibiting harmonic alternations in stressed mid-vowels: /ɛ/ and /ɔ/ raise to the mid-close [e] and [o], respectively, when followed by high vowels [i] and [u]. This harmony process is traditionally referred to as metaphony. Southern Salentino metaphony is characterized by variation in the way in which the unstressed [i] and [u] affect the stressed vowels /ɛ/ and /ɔ/. We examined the Southern Salentino dialect spoken in Tricase, focusing on both interspeaker and intra-speaker variation. Our primary goal is to understand the acoustic and articulatory characteristics of the metaphonic patterns and identify the features involved in this assimilatory process. Acoustically, we found that the metaphonic variant [e] has lower F1 and higher F2 values than /ɛ/, and the variant [o] exhibits lower F1 and F2 values than /ɔ/. We also show that the articulatory feature [±ATR] is significantly correlated with the metaphonic contrasts. Our second goal is to develop an appropriate phonological analysis of the phenomenon and describe the interacting parameters that generate the observed metaphonic variation. We argue that a key factor in the variation is the constraint against [+back, +ATR] vowels, which prevents high [+back, +ATR] triggers and/or mid [+back, +ATR] outcomes. After ruling out sociolinguistic factors, we propose that, although phonologized, the metaphonic process is still not fully normative in the community's speech, leading to both interspeaker and intra-speaker variation.

Keywords: variation; harmony; metaphony; phonologization; acoustic-articulatory analysis

We want to thank Francesco Sigona for his invaluable support in creating figures and conducting statistical analyses of the data. We are also grateful to Walter Shaw and three anonymous reviewers for their comments, which helped us improve the manuscript and the interpretation of the data. All errors are our own.

***Corresponding authors: Andrea Calabrese**, Department of Linguistics, University of Connecticut, Storrs, USA, E-mail: andrea.calabrese@uconn.edu; and **Mirko Grimaldi**, Department of Human Studies, Interdisciplinary Research Center on Language and Speech (CRIL), University of Salento, Lecce, Italy, E-mail: mirko.grimaldi@unisalento.it

Open Access. © 2026 the author(s), published by De Gruyter. This work is licensed under the Creative Commons Attribution 4.0 International License.

1 Introduction

1.1 Southern Salentino metaphony

The Italo-Romance Southern Salentino dialects feature a five-vowel system, as shown in (1):[1]

(1)
i u
ɛ ɔ
a

This system displays a harmonic process that raises stressed mid-vowels /ɛ/ and /ɔ/ to the mid-close [e] and [o] when followed by high vowels [i] and [u]. This process occurs whether the target vowels are in open or closed syllables (Grimaldi 2003, 2009). In Romance linguistics, this type of harmonic change is traditionally called metaphony; we will use this term here. Although Southern Salentino metaphony shows inherent variation, the data in (2) illustrate the most general form of the process: /ɛ, ɔ/ → [e, o]/ __[i, u]. The variation in this process will be discussed in Section 1.2.

(2)	a.	[ˈmɛtɛ]	“he reaps”	[ˈmeti]	“you reap”	[ˈmetu]	“I reap”
		[ˈbɛɖːɛ]	“nice” (pl. f.)	[ˈbeɖːi]	“nice” (pl. m.)		
		[ˈbɛɖːa]	“nice” (sg. f.)	[ˈbeɖːu]	“nice” (sg. m.)		
	b.	[ˈʃɔka]	“he plays”	[ˈʃoki]	“you play”	[ˈʃoku]	“I play”
		[ˈkrɔsːɛ]	“big” (pl. f.)	[ˈkrosːi]	“big” (pl. m.)		
		[ˈkrɔsːa]	“big” (sg. f.)	[ˈkrosːu]	“big” (sg. m.)		

To gain a better understanding of this process, we focus on Tricasino, the variety of Southern Salentino spoken in Tricase, already investigated by Grimaldi (2003) (cf. Figure 2). Our primary goal is to investigate the acoustic and articulatory characteristics of the metaphonic patterns and to establish what features are involved in the assimilatory process. We also aim to analyze which interacting parameters and restrictions control the spreading of the feature(s) responsible for the variation and to develop an appropriate phonological analysis. To our knowledge, acoustic-articulatory studies on Romance varieties displaying metaphony are lacking. Furthermore, very few studies have successfully explored harmony processes by combining phonetic and phonological approaches (cf. Benus and Gafos 2007; Gick et al. 2006).

1 Southern Salento is in the Province of Lecce in Italy’s Apulia region. The varieties affected by the metaphony under discussion are mainly found within the triangle formed by S.M. of Leuca in the south, Gallipoli in the west, and Otranto in the east; see Figure 2.

Our findings are as follows. Tricasino metaphonic patterns acoustically involve F1 variation with some effect on F2. On the articulatory side, Tricasino patterns are primarily correlated with the advancement of the tongue root and with subsequent general tongue adjustments of the dorsum. The most striking aspect of our investigation, however, is the discovery of complex interspeaker and intra-speaker variation in Tricasino, which parallels the one identified by Grimaldi (2003) across Southern Salentino varieties. Our phonological analysis will not only account for the metaphonic patterns highlighted by our acoustic and articulatory findings but also attempt to make sense of the variations that characterize these patterns in Tricasino and across all other Southern Salentino varieties.

In developing our analysis, we will highlight the important role that a constraint marking [+ATR] back vowels as phonologically complex plays in explaining the variation. This constraint will also be involved in the parameterization of tongue bunching, which we propose in Section 3.2.2 to account for differences in the articulatory realization of Southern Salentino [+ATR] vowels compared to those of other languages. Furthermore, we will argue that Southern Salentino metaphony is a recent innovation that has just emerged and is, therefore, independent of classical Italo-Romance metaphony, which dates back to the Middle Ages. We will also show that among its various patterns, it exhibits what can be described as a classic parasitic harmony, where [+ATR] spreading occurs only between vowels sharing the same [back] value (see Nevins 2010 for an integrated analysis of such harmony systems); parasitic harmonic systems are otherwise unknown in Italo-Romance. An analysis of how this harmonic system developed will be proposed in Section 6.

1.2 Metaphonic variation across Southern Salentino varieties

Grimaldi (2003, 2009) analyzed the vocalic productions in 36 localities in Southern Salentino by interviewing one speaker from each variety. His acoustic study showed that metaphony in Southern Salentino is affected by variation in the way in which the unstressed [i] and [u] affect the stressed vowels /ɛ/ and /ɔ/, generating the allophones [e] and [o]. Grimaldi's (2003, 2009) findings were based on a statistical model where *t*-tests were conducted separately for each condition (speaker, stem vowel, metaphonic vowel context). To strengthen our analysis and capture our generalizations as random effects in the observed data, we used a mixed-effects linear regression model in this article.

So, before proceeding, we preliminarily reanalyze the old data from the 36 Southern Salentino localities to make Grimaldi's data comparable to those obtained from the present investigation. We fitted a linear mixed model using a restricted maximum likelihood (REML) to predict F1 and F2 behavior separately: this was

implemented in the R statistical tool R (Core Team 2023) and the *lmer* package criterion (Bates et al. 2015). Each model had *TargetVowels* (/ɛ/, /ɔ/) and *TriggerVowels* ([i], [u]) as fixed factors, while *Locality* was included as a random intercept. *TriggerVowels* had three levels: namely, [i], [u] (the metaphonic triggers), and [e, a] (the nonmetaphonic triggers). *TargetVowels* had two factors: the target vowels /ɛ/ and /ɔ/.[2] The likelihood ratio test (function ANOVA) showed that the interaction between *TargetVowels* and *TriggerVowels* was statistically significant for F1 (χ^2 (2) = 259.14, p < 2.2E−16) and F2 (χ^2 (2) = 252.49, p < 2.2E−16). The results are illustrated in Table 1.

In Table 1, we observe that among the 36 speakers that were investigated, the most significant metaphonic patterns for F1 values involve the raising of /ɛ/ and /ɔ/ in specific contexts: /ɛ/ → [e] before [i], /ɔ/ → [o] before [i], and /ɔ/ → [o] before [u]. For F2 values, two significant metaphonic patterns emerge: /ɛ/ → [e] before [i] and /ɔ/ → [o] before [u]. Note that positive estimate values indicate an increase in F2, while negative values show a decrease (see the "Estimate" column in Table 1). Overall, the data suggest that the allophonic variants [e] and [o], triggered by unstressed [i] and [u], are raised in the acoustic space (F1 values decrease). Conversely, the allophonic variant [e], generated by [i], is more advanced in the acoustic space than the nonmetaphonized [ɛ] (F2 values increase). Importantly, the allophonic [o] produced by unstressed [u] is more posteriorized (F2 decreases) than the allophonic [o] triggered by [i] and the nonmetaphonized [ɔ].

We also used a linear model for the 36 localities to provide a comprehensive view of the raising effects caused by metaphony, as shown in Figure 1.

What emerges in Figure 1 is that, where metaphony is active, the pattern /ɛ/ → [e]/__[i] occurs systematically (with some localities only showing this pattern), while many varieties display only /ɛ/ → [e]/__[i] and /ɔ/ → [o]/__[u]. Additionally, in six localities, we can also find /ɔ/ → [o]/__[i], and in only two localities (Gagliano and Lucugnano), /ɛ/ → [e]/__[u].

The data in Figure 1 are geographically depicted in Figure 2, where we can also see the localities where metaphony is not active (for example, Casarano, Racale, Taviano, Ugento, among others). Thus, it appears that final [i] and [u] exhibit a clear asymmetry in their roles as metaphony triggers: [i] consistently triggers the metaphonic process, whereas [u] is often not a trigger and never the sole trigger. Systems where the only trigger is [u], such as /ɛ/ → [e]/__[u] or /ɛ, ɔ/ → [e, o]/__[u], are not attested. On the other hand, /ɛ/ and /ɔ/ show a distinct asymmetry concerning their

2 As for F1, conditional and marginal R^2 were 0.56 and 0.25, respectively (this difference is explained by considering that the sample contains both male and female speakers). Model intercept, corresponding to /ɛ/__[e], [a], was at 505.87 Hz (95% CI [491.79, 519.94], t(2152) = 70.47, p < .001). As for F2, conditional and marginal R^2 were 0.94 and 0.92, respectively, the model intercept was at 1873.24 Hz (95% CI [1850.77, 1895.70], t(2152) = 163.54, p < .001). The *glut* function of the *multcomp* package by Hothorn et al. (2008) was used.

Table 1: Results of the mixed-model analysis concerning the 36 Southern Salentino speakers. Significant metaphonic patterns for F1 and F2, (Pr(>|z|)), are highlighted by asterisks: ***extremely significant, **very significant; *significant. Negative Estimate for F1 indicates that formants decrease in metaphonic context (i.e., target vowels are raised), positive Estimate for F2 indicate that formants increase in metaphonic context (i.e., target vowels are anteriorized), and negative Estimate for F2 indicate that formants decrease in metaphonic context (i.e., target vowels are posteriorized).

Metaphonic versus nonmetaphonic contexts	**F1 Hz**				**F2 Hz**			
	Estimate	**Std. Dev.**	***Z* value**	**Pr(>|*z*|)**	**Estimate**	**Std. Dev.**	***Z* value**	**Pr(>|*z*|)**
[e]/__[i] versus [ɛ]/__[ɛ, a]	−78.667	3.537	−22.241	$p < 1e{-}04$***	173.928	8.759	19.857	$p < 1e{-}04$***
[e]/__[u] versus [ɛ]/__[ɛ, a]	−7.492	3.537	−2.118	$p = 0.122$	7.544	8.759	0.861	$p = 0.8362$
[o]/__[i] versus [ɔ]/__[ɛ, a]	−24.383	3.537	−6.894	$p < 1e{-}04$***	−20.306	8.759	−2.318	$p = 0.0749$
[o]/__[u] versus [ɔ]/__[ɛ,a]	−34.664	3.537	−9.800	$p < 1e{-}04$***	−39.689	8.759	−4.531	$p < 1e{-}04$***

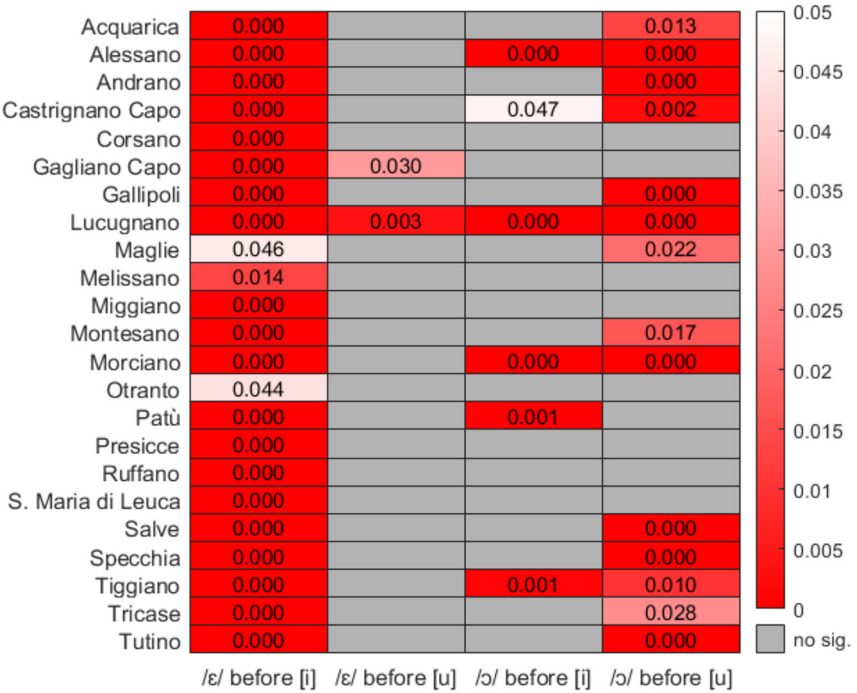


Figure 1: Different metaphonic action of unstressed [i] and [u] on preceding stressed /ɛ/ and /ɔ/ vowels for each speaker recorded in Southern Salento where metaphony is active (Grimaldi 2003). On the vertical axis: localities. On the horizontal axis: metaphonic contexts and whether metaphonic raising occurs in the environments listed. The levels of statistical significance are represented in each column with shades ranging from red (extremely significant level) to white (significant level). Gray = not significant. Note that in the Lucugnano variety, all metaphonic contexts display a very significant level.

roles as metaphony targets: /ɛ/ is the preferred target of Southern Salentino metaphony and is often the only target; /ɔ/ is never the only target. Therefore, a variety can display patterns like /ɛ/ → [e]/__[i] or /ɛ/ → [e]/__[i, u], but no variety shows only /ɔ/ → [o]/__[i], or /ɔ/ → [o]/__[i, u]. These data suggest that back vowels may hold a special status: unstressed [u] is less likely to be a metaphony trigger and stressed /ɔ/ is less likely to be a metaphony target. The only exception is the pattern /ɔ/ → [o]/__[u], which, along with /ɛ/ → [e]/__[i], is distinguished by a very significant statistical level.

So, the nature of this variation calls for an explanation. Is this type of variation typical of southern Salento varieties, or are we dealing with idiosyncratic processes of individual speakers interviewed in each locality?

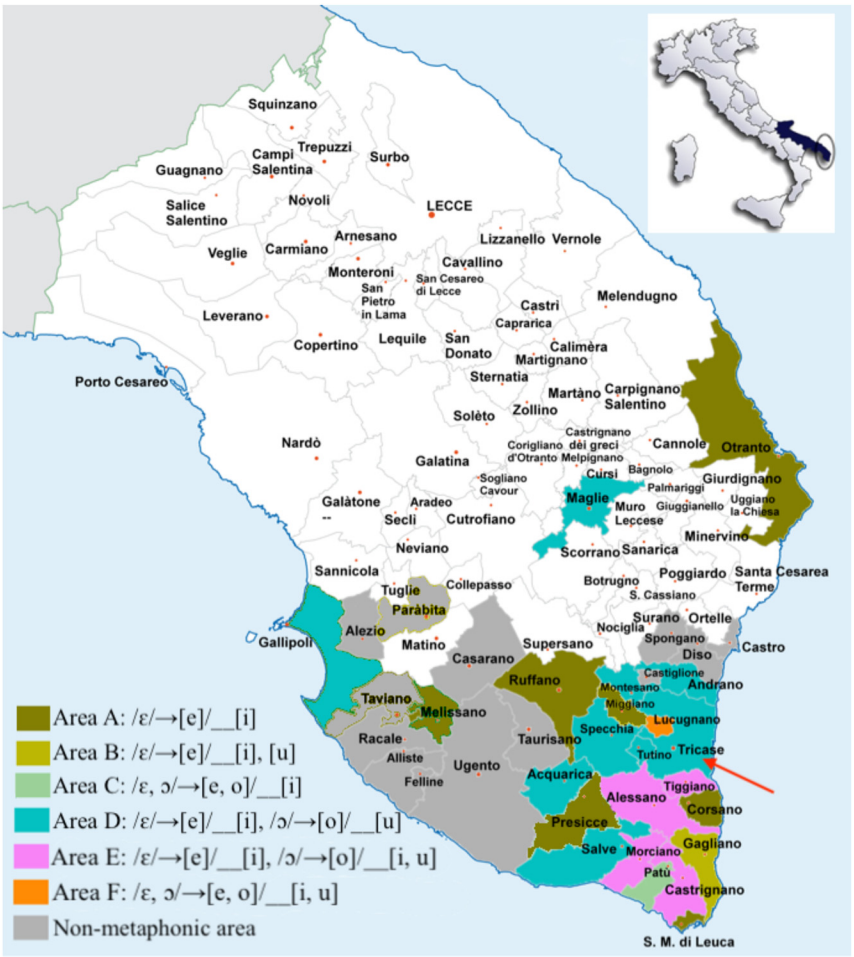


Figure 2: The province of Lecce and the southern Salento area roughly starting from the Gallipoli–Maglie–Otranto line. The localities with active metaphonic processes are colored based on the differing effects of the unstressed high vowels [i], [u] on the stressed mid vowels /ɛ/, /ɔ/. The nonmetaphonic area is highlighted in gray. The white area indicates localities that have not yet been investigated. Adapted from Grimaldi (2003).

1.3 The present study

Following Grimaldi et al. (2010), an investigation of the Tricase variety was carried out by Miglietta (2013), who conducted a preliminary acoustic analysis with 10 subjects. Her findings showed significant variation between speakers, indicating that the

same metaphonic patterns identified by Grimaldi (2003, 2009) in speakers of Southern Salentino varieties are also present in Tricasino speakers (see also Grimaldi and Calabrese 2018).

In this work, we refine the preliminary acoustic analysis by Miglietta (2013) by using a more suitable statistical method. Miglietta also collected ultrasound articulatory data for analysis in Professor Grimaldi's laboratory but was unable to do so. In this article, we analyze these articulatory data, selecting the best recordings to ensure reliable data for the statistical analysis. Although subject heads were stabilized (see Section 2.1.1), the probe under the subject's chin can shift due to head pressure or the subject may accidentally move their head during articulation – each experiment can last about 20 min – thus impacting the quality of the ultrasound images. Therefore, once we acquired the data, we carefully examined the tongue images: not all images were suitable for segmentation (see Figure 3) and were discarded. Including these data in the analysis would have introduced bias. Therefore, six speakers were included in the articulatory analysis (Experiment 1). The variation across different conditions puzzled us, leading to the hypothesis that variability might also be present within individual speakers' productions. In Experiment 2, we investigated intra-speaker variation: three Tricase speakers were asked to produce a set of words; after an hour, they repeated the same task. Only acoustic analysis was performed in this experiment. The same patterns of variation observed in Experiment 1 were also evident here.

2 Experiment 1: inter-speaker variation

2.1 Methods

2.1.1 Subjects, data acquisition, and analysis

Six speakers (two females; mean age 21.6, SD 1.21) were recorded: C.R. (f), M.M. (m), L.G. (m), G.E. (m), M.B. (f), G.G. (m). All subjects were native speakers of the Tricase variety. They were undergraduate students at the University of Salento and had only lived in Tricase. They generally used the Tricase variety with parents and friends. The stimuli were dialectal words – a subset of stimuli extracted from the questionnaire used in Grimaldi (2003) – containing the target vowels in both open and closed syllables. The selected words specifically included contexts where the metaphonic raising may occur (+met) or may not (−met), as exemplified in (3):

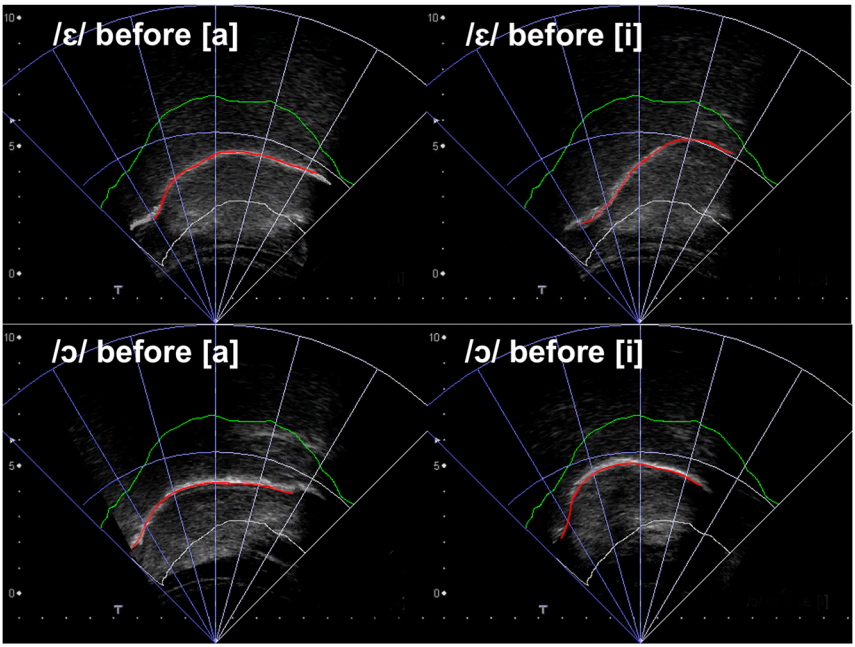


Figure 3: Examples of ultrasound images of /ɛ/ before [a], /ɛ/ before [i], /ɔ/ before [a], and /ɔ/ before [i] produced by the speaker LG (cf. Section 2.1.2). The red curve on the image shows the tongue surface contour; the green (above) and gray (below) curves indicate the boundaries within which AAA searches for the lower brighter edge and fits the tongue contour. The vertical axis displays the tongue height in centimeters.

(3)
	+met	/ɛ/ before [i]
	+met	/ɛ/ before [u]
	−met	/ɛ/ before [ɛ, a]
	+met	/ɔ/ before [i]
	+met	/ɔ/ before [u]
	−met	/ɔ/ before [ɛ, a]

The stressed high vowels /i/ and /u/ and the low vowel /a/ were also recorded separately. The list of stimuli is included in Appendix 1.

The subjects sat in a soundproof room and were asked to read word stimuli at a normal rate. These stimuli were embedded in a carrier phrase *Ieu ticu* ___ *moi* "I say ___ now" displayed on a computer screen. Ten stimuli for each of the five target vowels were used, designed to elicit the full vowel inventory in both open and closed syllables. The stressed /ɛ/ and /ɔ/ vowels were differentiated according to the unstressed vowel context. Speakers produced 10 words containing /ɛ/ before [i], 10

words with /ɛ/ before [u], and 10 words with /ɛ/ before [ɛ] or [a] (these two vowels were grouped together as they do not trigger different metaphonic assimilations), and the same applied for /ɔ/. When possible, words were chosen so that /ɛ/ and /ɔ/ were surrounded by labial and labiodental consonants that have minimal effects on the tongue body and root position. In total, 90 stimuli per subject, including 10 stimuli for each of the corner vowels /i, a, u/, were randomly interchanged for elicitation, amounting to 540 stimuli in all.

The stimuli were recorded with a Shure SM58_LCE microphone, using the CSL 4500 recording system at a sampling rate of 22.05 kHz with 16-bit precision. All speaker productions were segmented and normalized in peak amplitude using Praat 5.2 (Boersma and Weenink 2011). For each vowel, total duration as well as F0, F1, F2, and F3 were measured; however, for this work, only F1 and F2 were considered for further analysis because these formants are the main acoustic features involved in harmony processes (see Sections 2.1.2 and 3.2.1). The formant values were measured in the vowel steady state (0.025 s) centered at the midpoint.

An Aplio XV machine by Toshiba Medical System Corp. was used to acquire ultrasound images of tongue contours at 25 Hz. The video stream was synchronized with the audio signal using an external analog-to-digital A/V acquisition card and was recorded in real-time on a dedicated PC (cf. Grimaldi et al. 2016). The ultrasound probe was securely fixed in a stable position on an appropriately adapted microphone stand. To prevent transducer pressure on the soft tissue of the jaw, an acoustic standoff was used to eliminate upward pressure on the tissue. The two sides of the subject's head were stabilized with an adjustable wooden system built at the *Centro di Ricerca Interdisciplinare sul Linguaggio* (CRIL). This setup allows the speaker to rest their forehead steadily so that the entire tongue contour – from the tip to the shadow of the hyoid bone – can be captured and analyzed. The ultrasound A/V stream was segmented offline by an automatic software procedure developed at CRIL, based on audio pulses superimposed on the speech signal before and after each sentence during recording (Grimaldi et al. 2016). For each segmented sentence, the operator manually labeled the relevant vowel time intervals by examining the acoustic waveform, ensuring that the corresponding ultrasound images could be identified.

The analysis of the ultrasound data was focused on the following typology of vowels:

– The metaphonic targets /ɛ/, /ɔ/ before [i], [u], and [ɛ, a]
– The unstressed triggers [i], [u]

The next step in ultrasound data analysis was to fit the tongue contour to the lower edge of the bright curve representing the tongue surface. This was performed semi-

automatically using the *Articulate Assistant Advanced* (AAA) software by Articulate Instruments Ltd.

First, the region where the software searches for the brightest lower edge was defined. When the AAA detects such an edge, a contour is fitted to it. However, this fitting is not perfect. All frames must be inspected, and the fitted contours need to be manually corrected. The red curve on the image shows the tongue surface contour, while the green and gray curves indicate the boundaries within which AAA searches for the lower brighter edge and fits the tongue contour. Examples of fitted tongue contours are shown in Figure 3.

2.1.2 Statistical analysis

We used a linear mixed model for the acoustic analysis to predict F1 and F2 separately: the model had *TargetVowels* (/ɛ/, /ɔ/) and *TriggerVowels* ([i], [u]) as fixed factors. The model included *Subjects* as random effects. *TriggerVowels* had three levels: namely, [i], [u] (the metaphonic triggers), and [e], [a] (the nonmetaphonic triggers). *TargetVowels* had two factors: that is, the target vowels /ɛ/ and /ɔ/.[3] For both F1 and F2, we analyzed the multiple comparisons of means for the relevant contrasts.

To understand which articulatory feature is involved in Tricase metaphony, we used the Smoothing Spline ANOVA approach to compare tongue curves (Davidson 2006; Gu 2002). The Smoothing Spline ANOVA is an inferential statistical method used to examine similarities and differences in the shapes of two groups of curves. It is commonly applied in medical science, environmental science, and epidemiology and can also be used to compare groups of tongue curves produced by the same individual. In our case, for each subject, the tongue curves recorded from 10 repetitions of /ɛ/ before [i] and [u] are compared with the curves from 10 repetitions of /ɛ/ before [ɛ]/[a], as well as with the curves obtained from 10 repetitions of the metaphonic triggers [i] and [u]. The same comparison was performed with /ɔ/ (cf. Section 2.1.1).

This statistical method has the advantage of determining whether there are significant differences between the tongue curves of two groups and which sections – i.e., root, body, or blade of the tongue curves – differ (Davidson 2006). When multiple repetitions of an utterance are collected, smoothing splines combined with Bayesian confidence intervals are an appropriate way to model the shapes that best fit the data and account for variance in production (Davidson 2006). Given two groups of tongue

3 Our findings for F1 are significant, with conditional and marginal R^2 at 0.76 and 0.19, respectively: the difference can be explained considering that the sample contains both male (LG, MM, GE, and GC) and female subjects (CR and MB). The model intercept corresponding to /ɛ/__[ɛ, a] was at 560.65 Hz (95% CI [511.38, 609.91], t(503) = 22.36, p < .001). As for F2, conditional and marginal R^2 were 0.96 and 0.90, respectively, and the model intercept was 1885.95 Hz (95% CI [1794.58, 1977.32], t(503) = 40.55, p < .001).

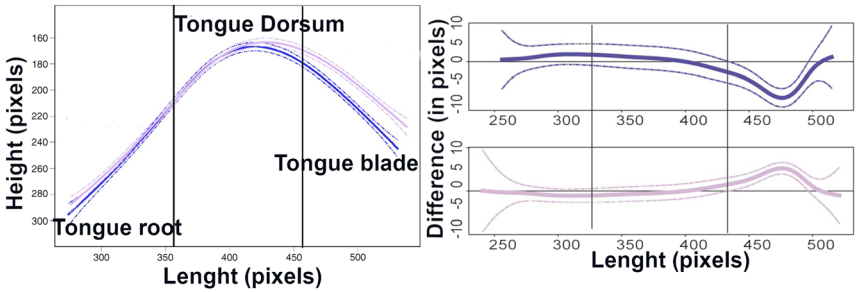


Figure 4: On the left, the smoothing spline estimate and 95 % Bayesian confidence interval for comparison of the mean curves for /g/ in *bag dazzled* (dark blue line) and *Baghdad* (pink line), produced by an American English native male speaker. On the right, interaction effects with Bayesian confidence intervals illustrate the shapes of /g/ in *bag dazzled* and *Baghdad*. The splines representing the interaction effect are mirror images because they show the difference between the main effect spline and the spline that best fits all data for each word. Both images are displayed because the confidence intervals can vary. The *x-axis* represents length, and the *y-axis* shows the difference between each data set and the spline fitting all data for *bag dazzled* and *Baghdad*. When the confidence interval encompasses 0, the curves are not significantly different. The short, thick lines in each image indicate the parts of the interaction curve that are not significantly different. Adapted from Davidson (2006).

curves, the corresponding Smoothing Splines are computed: they are curves that provide the best fit to all data points within each group (cf. Figure 4).

The Smoothing Spline for each data set is called the *main group effect* and is constructed around the 95 % Bayesian confidence interval. The comparison between the two groups of tongue curves is performed with the *interaction diagram*, which plots the difference between the Smoothing Spline for each data set and the Smoothing Spline that best fits all the data. Then, the 95 % Bayesian confidence interval is constructed again, and the difference between the splines is considered significant when the confidence interval does not include zero on the *y*-axis (cf. Figure 4). The Smoothing Spline ANOVA analysis was performed using a MATLAB tool developed at CRIL and the R package *gss* (Gu 2002).

2.2 Results

2.2.1 Acoustic results

The likelihood ratio test showed that the interaction between *TargetVowels* and *TriggerVowels* was statistically significant both for F1 (χ^2 (2) = 148.09, p < 2.2E−16) and F2 (χ^2 (2) = 118.19, p < 2.2E−16). The results of the multiple comparison of F1/F2 means for the relevant contrasts and for all subjects are illustrated in Table 2 (cf. Appendix 2,

Experiment 2, for mean F1-F2 formant values per speaker in Hz, along with standard deviation, minimum, and maximum).[4]

The significant metaphonic effects among the six speakers are also visually summarized in Figure 5: different shades of red indicate the levels of statistical significance achieved by each metaphonic pattern. The significant metaphonic effects are shown by aligning each Tricase speaker on the vertical axis with the potential metaphonic patterns on the horizontal axis.

In Figure 6, the /i/, /a/, /u/ vowels, along with the allophonic variants of the mid-vowels /ɛ/, /ɔ/ produced by the six speakers, are plotted in a two-dimensional F1–F2 Hz space using ellipses on data (the figure was created using the R statistical package McCloy 2015). It is important to note that within the ellipses representing the acoustic data for /ɛ/___[ɛ, a] and /ɔ/__[ɛ, a], there is no dispersion (i.e., no significant standard deviation from the mean): this indicates that unstressed [ɛ] and [a] behave similarly, and, contrary to unstressed [i] and [u], are not metaphonic triggers (as shown by Grimaldi 2003). Conversely, if [a] were a metaphonic trigger, we would expect ellipses to shift toward higher F1 values because of the assimilatory process affecting these vowels.

2.2.2 Articulatory results

For each speaker, the articulatory gesture related to a specific metaphonic pattern is shown in Figures 7–11.

The allophonic variant generated by metaphony is compared with the trigger (i.e., the unstressed vowels [i] or [u]) and with the tongue gesture not related to metaphony assimilation (i.e., /ɛ/, /ɔ/ before [ɛ, a]). The tongue blade is visible on the right, the tongue body is raised in the center, and the tongue root is lowered on the left of the tongue contours. Below each tongue contour, the interaction diagrams are shown for both the affected mid-vowels and the control cases not affected by metaphony (see Section 2.1.2, Figure 4).

Note that the different curves in Figures 7–11 reflect statistical effects derived from actual tongue contours captured through ultrasound images (as explained in Sections 2.1.1 and 2.1.2). Therefore, small changes in curve shapes (on the order of millimeters) result from different anatomical tongue positions that produce significant acoustic effects. In other words, the significant acoustic differences observed

4 Note that the mixed model takes into account the general significant effects among all speakers. As seen in Figure 5, only one speaker, LG, has the pattern /ɛ/ → [e]/__[u], which is therefore not significant among the speakers.

Table 2: Results of the mixed-model analysis concerning the 6 Tricasino subjects investigated. For each metaphonic context (left column), significant metaphonic patterns for F1 and F2 are highlighted by asterisks: ***extremely significant, **very significant; *significant. Negative Estimate for F1 indicates that formants decrease in metaphonic context (i.e., target vowels are raised), positive Estimate for F2 indicates that formants increase in metaphonic context (i.e., target vowels are anteriorized), and negative Estimate for F2 indicates that formants decrease in metaphonic context (i.e., target vowels are posteriorized).

Metaphonic versus nonmetaphonic contexts	F1				F2			
	Estimate	Std. Err.	*Z* value	Pr(>|*z*|)	Estimate	Std. Err.	*Z* value	Pr(>|*z*|)
[e]/__[i] versus [ɛ]/__[ɛ, a]	−98.717	6.054	−16.306	<1e−04***	209.77	15.07	13.919	<1e−04***
[ɛ]/__[u] versus [ɛ]/__[ɛ, a]	−7.714	6.028	−1.280	0.5716	−13.16	15.01	−0.877	0.83830
[o]/__[i] versus [ɔ]/__[ɛ, a]	−16.158	5.880	−2.748	0.0233*	−23.78	14.64	−1.625	0.34146
[o]/__[u] versus [ɔ]/__[ɛ, a]	−42.894	5.880	−7.295	<1e−04***	−47.85	14.64	−3.269	0.00425**

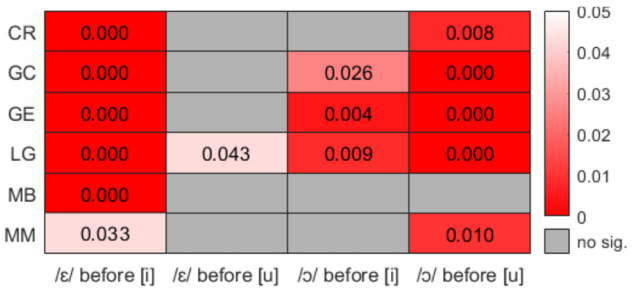


Figure 5: Different metaphonic effects of unstressed [i] and [u] on preceding stressed /ɛ/ and /ɔ/ vowels for the six Tricase speakers. Vertically: the speakers. Horizontally: the metaphonic contexts /ɛ/ before [i], /ɛ/ before [u], /ɔ/ before [i], and /ɔ/ before [u]. The levels of statistical significance are shown in each column with shades from red (extremely significant) to pink (significant). Gray indicates not significant.

between mid-vowels affected by metaphony ([ɛ] vs [e] and [ɔ] vs [o]) are caused by distinct tongue articulations, which will be discussed in the next section.

A detailed interpretation of the data represented in Figures 7–11, together with the acoustic outputs in Figure 6, is given in Table 3.

3 Preliminary discussion

3.1 Acoustic-articulatory properties of Southern Salentino metaphony

The results of the Tricasino interspeaker investigation align with those found by Grimaldi (2003, 2009), who studied one speaker from each locality. On the acoustic level, it confirms that /ɛ/ → [e] before [i] and /ɔ/ → [o] before [u] are the most significant metaphonic patterns; /ɔ/ → [o] before [i] is also present. As shown in Table 2, [e] followed by [i] is raised and advanced in the acoustic space (with F1 values decreasing and F2 values increasing); [o] followed by [u] is raised and moved posteriorly (both F1 and F2 decrease), while [o] followed by [i] is simply raised. Importantly, beyond these systematic patterns, we observe that Tricasino speakers do not display stable metaphonic patterns, as Figure 5 clearly demonstrates, paralleling Grimaldi's (2003) data shown in Figure 1 (see also Section 4.2).

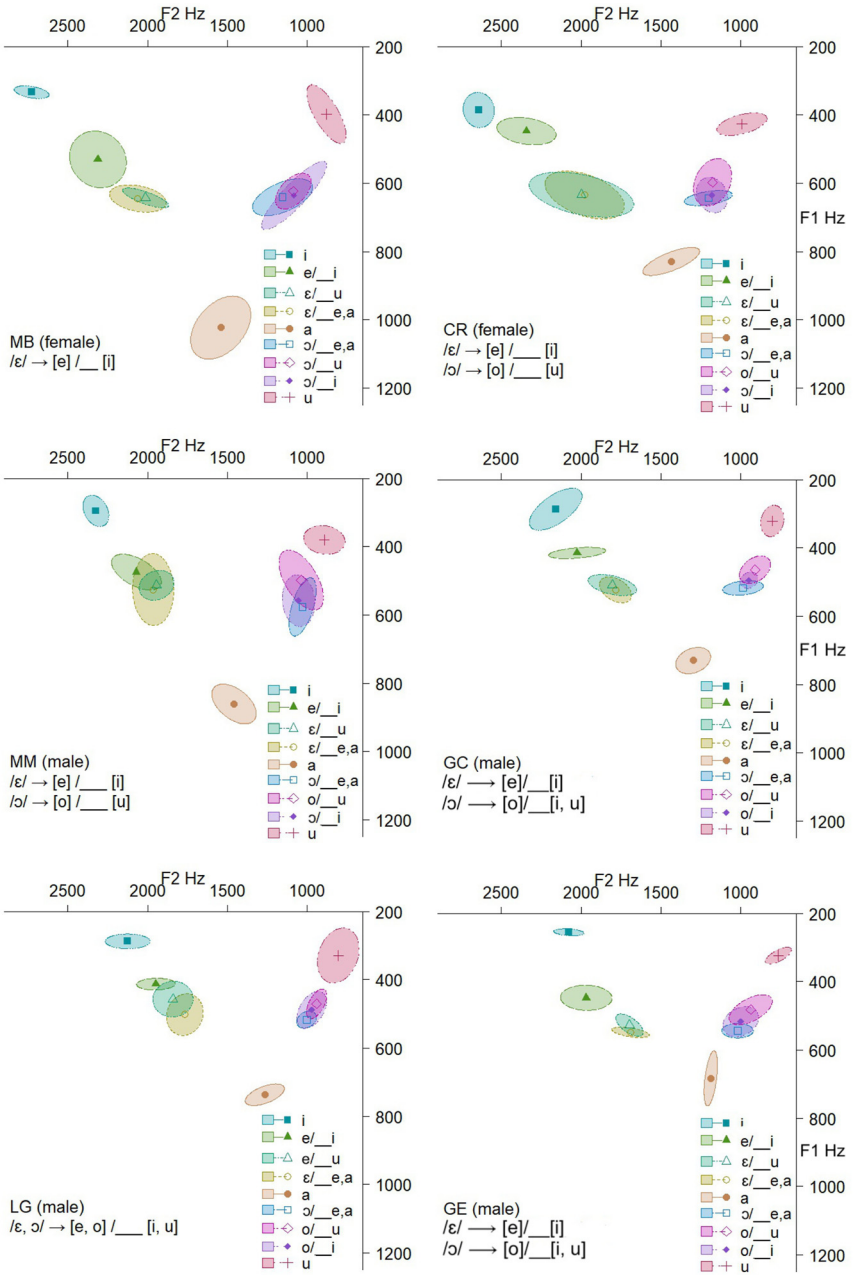


Figure 6: Scatter plots based on F1 and F2 Hz values of the 6 Tricase speakers investigated. For each subject, significant metaphonic adjustments affecting the mid-vowels /ɛ/, /ɔ/ are shown and described below left. Different colors and symbols represent different vowel categories. Each ellipse encompasses 68.8 % of data points for one vowel category.

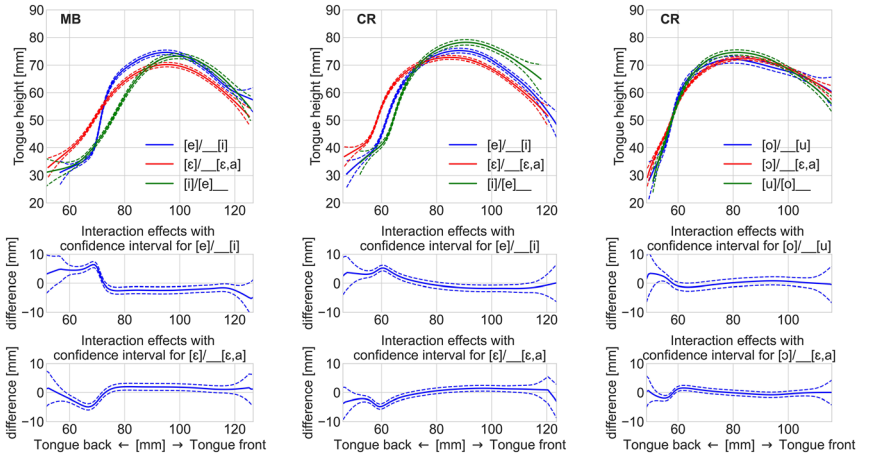


Figure 7: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in subjects MB: /ɛ/ → [e]/__[i] (on the left), and CR: /ɛ/ → [e]/__[i] (in the center), /ɔ/ → [o]/__[u] (on the right).

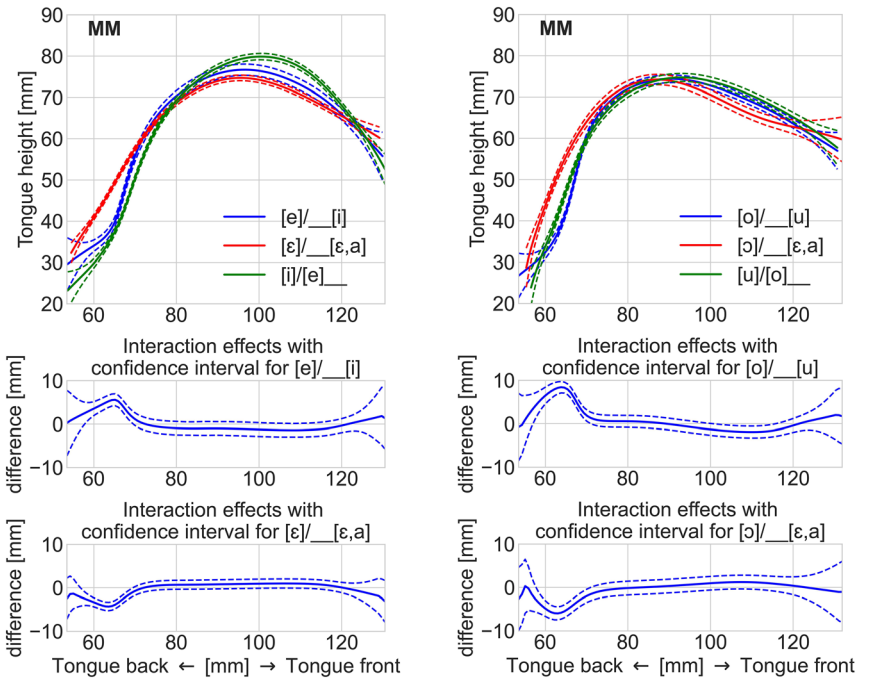


Figure 8: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in subject MM: /ɛ/ → [e]/__[i] on the left, /ɔ/ → [o]/__[u] on the right.

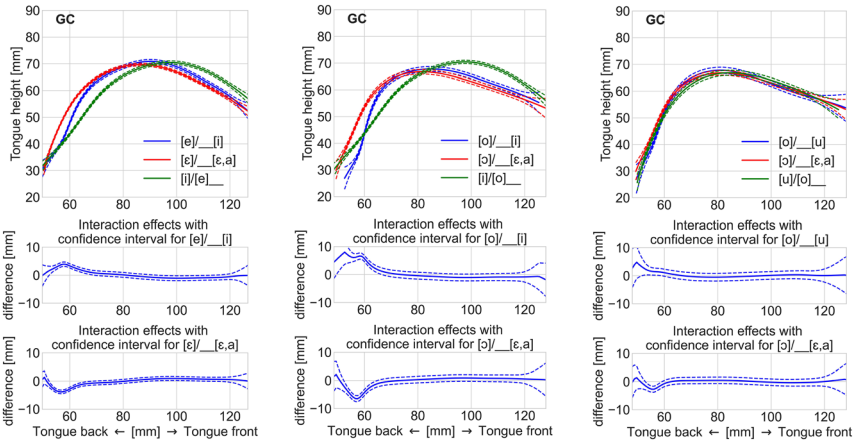


Figure 9: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in subject GC: /ɛ/ → [e]/__[i] top left, /ɔ/ → [o]/__[i] top in the center, /ɔ/ → [o]/__[u] top in the right.

Overall, the findings of Experiment 1, along with those of Grimaldi (2003), indicate that the main acoustic feature of the Southern Salentino metaphonic patterns is the lowering of the first formant (F1). From a purely acoustic perspective, the differences in metaphonic allophones stem from the difference in F1 values. In Figure 12, we illustrate the significant change in F1 relative to the triggers [i], [u] on both targets /ɛ/, /ɔ/ for male speaker LG whose acoustic data are shown in Figure 12. Using the data in Figure 12, we emphasize that metaphony does not result in a complete assimilation of the F1 values of the stressed mid-vowels with those of the unstressed high vowels. In fact, the F1 values of [e] and [o] do not overlap with the F1 values of [i], [u], the vowels that trigger metaphony. Instead, the assimilation process creates two distinct allophonic categories on both the front and back axes.

The overall effect here from metaphonic assimilations is the raising of allophonic variants in the acoustic space. As shown in Figures 6–11 and Tables 1, 2, our findings indicate that F1 lowering results from tongue root advancement. Therefore, we suggest that the allophonic contrasts [ɛ]–[e] and [ɔ]–[o] are generated by exploiting the [±ATR] feature. We also hypothesize that this feature, along with [high] and [low], explains vocalic height contrasts. According to our analysis, this feature underlies distinctions such as tense/lax and close/open, which are commonly used to explain similar vocalic contrasts in the Romance and Germanic phonological literature. The next section discusses this issue.

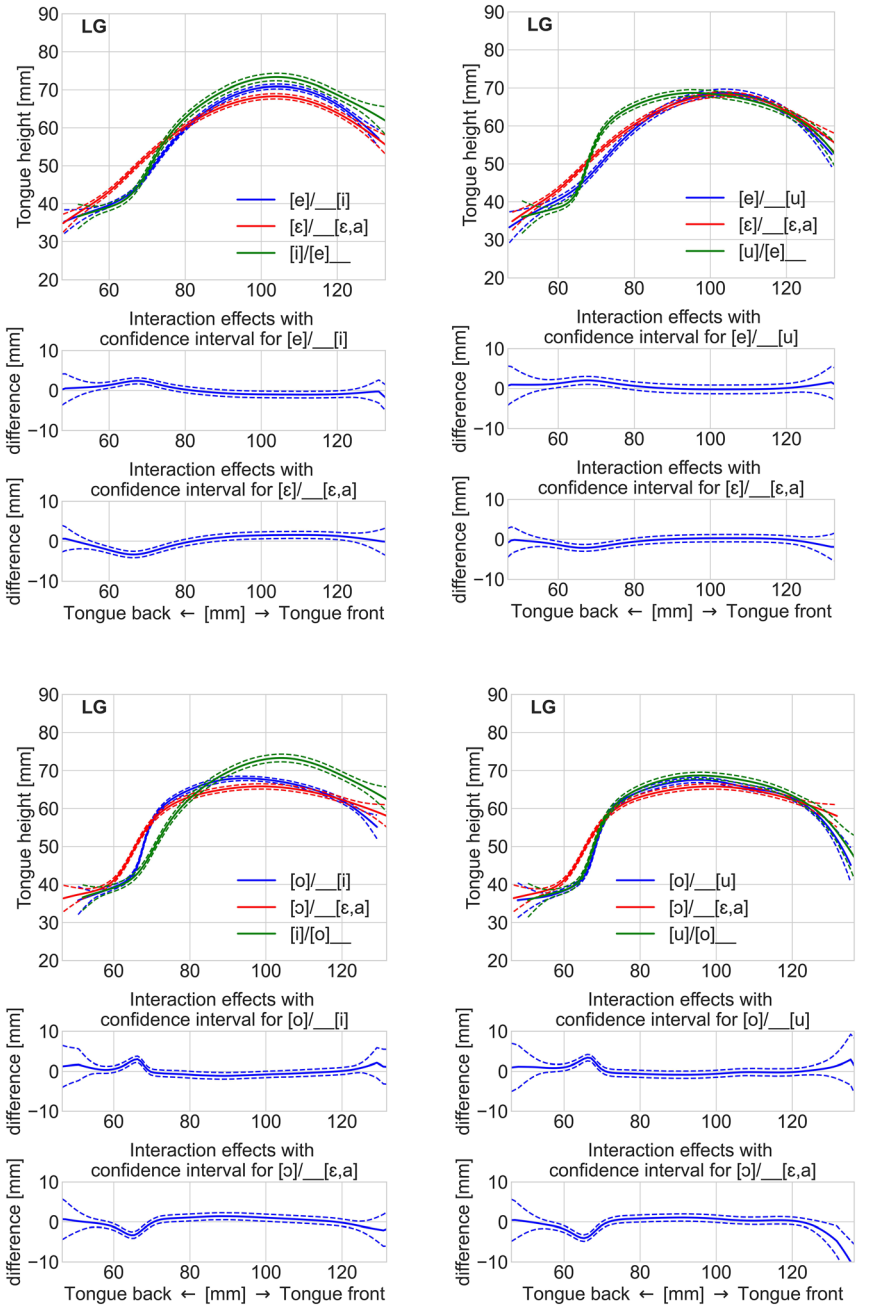


Figure 10: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in subject LG: /ɛ/ → [e]/__[i] top left, /ɛ/ → [e]/__[u] top right, /ɔ/ → [o]/__[u] bottom left, /ɔ/ → [o]/__[u] bottom right.

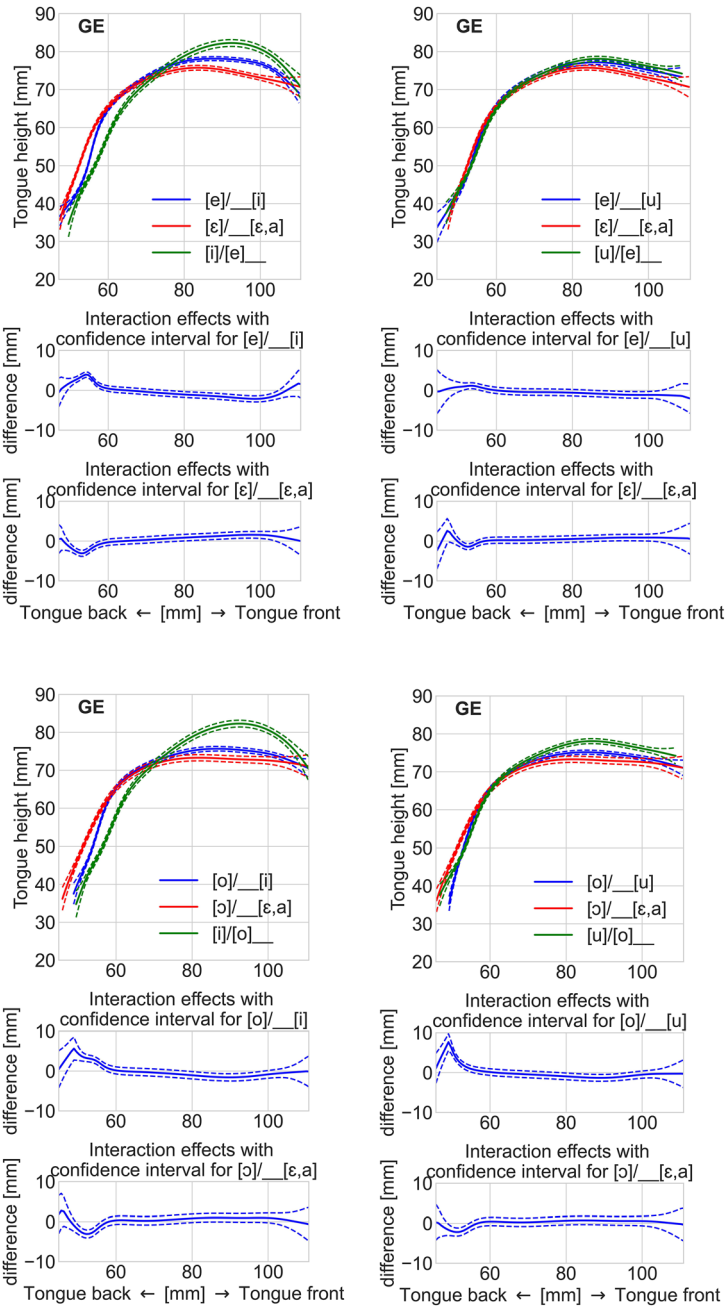


Figure 11: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in subject GE: /ɛ/ → [e]/__[i] top left, /ɛ/ → [e]/__[u] top right, /ɔ/ → [o]/__[i] bottom left, /ɔ/ → [o]/__[u] bottom right.

Table 3: A detailed description of metaphonic patterns with significant tongue root advancement and dorsum raising configurations, along with their acoustic outputs, is provided for each subject. **very significant; *significant; an asterisk in parentheses indicates borderline statistical significance; /not significant.

Subjects	Metaphonic patterns	Interaction effects Root advancement	Interaction effects Dorsum raising	Acoustic outputs
M.B. (f.)	/ɛ/ → [e]/__[i]	**	*	Raising + front
C.R. (f.)	/ɛ/ → [e]/__[i]	**	*	Raising + front
	/ɔ/ → [o]/__[u]	**	/	Raising
M.M. (m.)	/ɛ/ → [e]/__[i]	**	/	Raising + front
	/ɔ/ → [o]/__[u]	**	/	Raising
G.C. (m.)	/ɛ/ → [e]/__[i]	**	/	Raising + front
	/ɔ/ → [o]/__[i]	**	/	Raising
	/ɔ/ → [o]/__[u]	**	/	Raising
G.E (m.)	/ɛ/ → [e]/__[i]	**	*	Raising + front
	/ɔ/ → [o]/__[i]	**	(*)	Raising
	/ɔ/ → [o]/__[u]	**	(*)	Raising + posterior
L.G. (m.)	/ɛ/ → [e]/__[i]	*	/	Raising + front
	/ɛ/ → [e]/__[u]	*	/	Raising
	/ɔ/ → [o]/__[i]	*(*)	/	Raising
	/ɔ/ → [o]/__[u]	*(*)	/	Raising + posterior

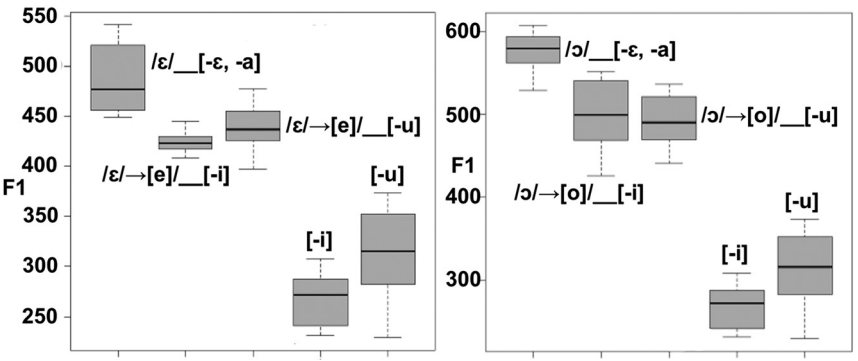


Figure 12: Statistical distribution of F1 Hz values for metaphonic targets and triggers for speaker LG, presented as an illustrative example. The metaphonic effects /ɛ/ → [e]/__[i], /ɛ/ → [e]/__[u] on the left and /ɔ/ → [o]/__[i], /ɔ/ → [o]/__[u] on the right are shown. Also, the no-metaphonic contexts /ɛ/__[ɛ, a] (on the left) and /ɔ/__[ɛ, a] (on the right) are represented.

3.2 The feature [ATR]

3.2.1 Acoustic correlates

As shown by the data above, F1 lowering is the main acoustic correlate of the ATR feature. This means that [+ATR] vowels are produced higher in the acoustic space than [−ATR] vowels (Archangeli and Pulleyblank 1994; Beltzung et al. 2015; Gick et al. 2006; Guión et al. 2004; Halle and Stevens 1969; Kirkham and Nance 2017; Maddieson 2003). Therefore, F1 values are not only inversely related to tongue height – the higher the tongue rises from its resting position, the lower the F1 values – but also to tongue root advancement/non advancement. As Archangeli and Pulleyblank (1994: 7) state: "the primary acoustic correlate of tongue-root advancement is a lowering of the first formant frequency, while tongue-root retraction correlates with a raising of the same formant."

F2 differences are also believed to play a role in [ATR] contrasts, although, according to Ladefoged (1968) and Lindau (1979), F2 values are not a reliable cue for [+ATR] distinctions in vowels. Front [+ATR] vowels tend to be higher and more advanced in the acoustic space than front [−ATR] vowels, which are lowered and centralized (Halle and Stevens 1969; Ladefoged and Maddieson 1996: 306). In contrast, with back vowels, cross-linguistic variation is evident. In some languages, back [+ATR] vowels have lower F2 than [−ATR] ones, making them acoustically further back compared to the centralized [−ATR] vowels. For example, German shows lower F2 values for [uː] and [o] than for their [-ATR] counterparts [ʊ] and [ɔ] (Bergmann et al. 2016; Hillenbrand et al. 1995; Jessen 1998; Kirkham and Nance 2017; Stevens 2000; Yang 1996). Conversely, some languages display the opposite pattern: in these cases, it is the [-ATR] back vowels that have lower F2 values, indicating they are further back acoustically than their [+ATR] counterparts. For example, this is demonstrated in Niger-Congo languages, as analyzed by Ladefoged and Maddieson (1996: 300–306), who studied contrasts due to tongue root position (see the next section for further discussion).

In Southern Salentino, the [+ATR] feature of the metaphonic vowel [e] correlates with F1 lowering and F2 raising, aligning with the cross-linguistic patterns discussed above. This indicates that the [e] produced by metaphony is realized higher and more fronted than its nonmetaphonized equivalent [ɛ]. Meanwhile, the mid-back [+ATR] vowel [o] generated by metaphony typically shows similar F1 lowering (Grimaldi 2009; Grimaldi et al. 2010), but, unlike [e], its F2 is lowered. This suggests greater acoustic posteriorization, as discussed below.

3.2.2 Articulatory correlates

In articulatory terms, the primary correlate of the ATR feature clearly involves the presence or absence of tongue root advancement (Gick et al. 2006; Ladefoged 1968). Additional articulatory data indicate that tongue root advancement may also be linked to laryngeal lowering and pharyngeal cavity expansion (Esling et al. 2019; Lindau 1975; Moisik et al. 2021). Therefore, pharyngeal expansion is likely the main correlate of [±ATR] contrasts, rather than just tongue root activity, which led Lindau (1979) to propose the feature [EXPANDED] instead of [ATR]. Lindau's analysis is supported by other instrumental studies showing that the [±ATR] contrasts in Niger-Congo varieties may involve more than just tongue root advancement, such as lateral expansion of the pharynx for Akan (Ladefoged 1968; Lindau 1979; Lindau et al. 1972; Lindau-Webb 1987; Painter 1973; Stewart 1967; Tiede 1996). Alongside Lindau's findings, this suggests that tongue root advancement is only one possible factor in producing what is generally called [±ATR] contrasts. Tongue body bunching could also be part of this complex mechanism. These components appear to work synergistically in controlling these phonological contrasts (Esling et al. 2019; Moisik et al. 2021; Tabain et al. 2024).

Unfortunately, as discussed further below, the ultrasound techniques we used in our articulatory research do not allow us to evaluate the articulatory behavior of the lower pharynx and larynx in Tricasino metaphonic alternations. Therefore, we conservatively rely on the feature [ATR] to describe their behavior; however, we are supportive of the idea that tongue root advancement or nonadvancement could be part of a larger articulatory strategy involving other lower tract components such as the pharynx and larynx (Esling et al. 2019; Moisik et al. 2021), and we hope to explore this further in future research.

We assume that these synergistic mechanisms in the vocal tract are also responsible for the tongue dorsum configurations. In particular, the articulatory gesture involved in [+ATR] vowels may give the longitudinal profile of the tongue a tighter curve than it has in its neutral configuration. Thus, Lindau (1978) observes that advancing the tongue root tends to push the tongue body up and forward (see also Archangeli and Pulleyblank 1994; Calabrese 2001, 2016), as schematized in (4):

(4) [+ATR] → fronting and raising of tongue body

In fact, due to the tongue's hydrostatic properties (Gilbert et al. 2007; Kier and Smith 1985) – the tongue is an elastic mass – the shape of the tongue body is not entirely independent of tongue root position and pharyngeal expansion or constriction. Therefore, in front [+ATR] vowels, tongue root advancement can cause the anterior part of the tongue to bunch up (cf. Figures 7–11). This results in a tighter-than-neutral curve at the tip and blade of the tongue (Laver 1994: 142), leading to a higher position

of the tongue dorsum relative to front [−ATR] vowels. For [+ATR] back vowels, it is crucial to prevent full front dorsum advancement. However, tongue root advancement may still cause bunching of the back dorsum and a tighter-than-neutral curve, which can make these back vowels higher and more posterior than their [−ATR] counterparts (see below for further discussion).[5]

Importantly, it appears that the relationship between tongue height and tongue root position varies across languages in distinguishing vowel contrasts. For example, it has been shown that tongue height is not significantly correlated with tongue root position in West African Niger-Congo phonological systems like Akan, Igbo, Dagbani, Twi, Kabiye, and Yoruba (Allen et al. 2013; Edmondson et al. 2007; Hudu 2010; Hudu et al. 2009; Kirkham and Nance 2017; Ladefoged 1968; Lindau 1979; Tiede 1996), as well as in other African languages such as Kinande, Maa, and Somali (Edmondson et al. 2007; Gick et al. 2006; Guión et al. 2004). In these languages, the advancement/nonadvancement of the tongue root seems to form the basis of [ATR] contrasts, along with potential modulating behaviors of the larynx and pharynx. Conversely, in English and German, the movement of the tongue root correlates with tongue height in the distinctions between tense and lax vowels (Ladefoged and Maddieson 1996; also see Kirkham and Nance 2017).

We suggest that this typological variation in [ATR] vocalic contrasts results from a phonetic parameter involving the inhibition or noninhibition of tongue body bunching, which occurs in the presence of tongue root advancement and possibly pharyngeal expansion or larynx lowering (Esling et al. 2019; Moisik et al. 2021). If tongue body bunching is inhibited, the relevant vocalic contrast is only due to the advancement/nonadvancement of the tongue root. If there is no inhibition, then advancement or nonadvancement of the tongue root will result in tongue body dislocations, which will then correlate with differences in tongue height. The ultrasound technique does not provide information about the behavior of the pharynx, as the data do not image the laryngeal mechanism at all. However, based on the literature discussed above, we can speculate that in our case, pharyngeal expansion or constriction might also serve as a gesture controlling the Tricasino metaphony (cf. Esling et al. 2019; Moisik et al. 2021). Only future research using specific techniques can lead to a thorough understanding of the lingual–laryngeal (and pharyngeal) relationships involved in our [ATR] allophonic contrasts.

Let us return to the issue of [ATR] contrasts sometimes involving F2 differences. It is reasonable to assume that these differences result from tongue body bunching. Remember that in back vowels, bunching causes a higher and more posterior position of the back dorsum, which leads to a lowering of F2. As mentioned earlier, variation in

5 It is important to note that back [+ATR] vowels are indeed fronted in a several languages (cf. for instance, in Somali). See Calabrese (2001, 2016) for further examples and discussion.

F2 seems to occur only for back vowels. In West African Niger-Congo languages, the back [+ATR] vowels tend to have higher F2 values than their [−ATR] counterparts, which are positioned further back in the acoustic space. Conversely, in German and our Salentino varieties, the back [+ATR] vowels usually have lower F2 values than their [−ATR] counterparts, which are more advanced in the acoustic space. If there is a correlation between F2 changes and tongue bunching, it suggests that parametric variation in tongue body bunching is limited to back vowels: some languages permit tongue bunching in back vowels, while others do not. This could explain the difference between West African Niger-Congo languages and Germanic languages. Only the latter group allows tongue bunching for [+ATR] back vowels, resulting in lower F2 for these vowels compared to the [−ATR] back vowels. The opposite pattern is found in the former languages, such as Akan, Igbo, Kinande, and others.

We present this as a baseline. This raises the obvious question of why there's an asymmetry between front [+ATR] vowels and their back counterparts: the front vowels always involve tongue body bunching, while the same bunching in the back vowels is systematically parametrized. We propose that this asymmetry results from the fact that [+ATR] back vowels cannot fully advance the dorsum to the front; doing so would turn them into front vowels and cause them to miss their back acoustic target. Therefore, bunching is either entirely suppressed – such as in the West African languages mentioned earlier – or it is regulated so that only the back dorsum is drawn tighter than neutral. In this case, back [+ATR] vowels are higher and more posterior compared to [−ATR] vowels. The second scenario applies to German and Romance languages, at least for the Salentino system (additional acoustic-articulatory research is needed to clarify this further).

There are a few complications that need to be mentioned. First, the high-back lax vowel [ʊ] in both British and American English may have low F2 values, causing it to be further back than its tense counterpart [u]. The same pattern may also be observed for the mid-back lax vowel [ɔ], more consistently in British English than in American English. We suggest that this could be due to the direction of bunching. Even if controlled so that the back [+ATR] vowels do not become front, the bunching might lead to a more central or forward dislocation of the tongue body. This could explain the difference between English and German: English bunched-up [+ATR] vowels seem to be more forward than their German counterparts (see Ladefoged and Maddieson 1996).

On the other hand, recent studies show that even in some Niger-Congo varieties, F2 lowering occurs only with the high [-ATR] vowels and not with the mid [+back] [o]. Unlike its high counterpart, this vowel shows more F2 lowering than [-ATR] [ɔ], which becomes more centralized in the acoustic space (cf. Anderson and Grace 2008; Gick et al. 2006; Tiede 1996). Assuming that this is not due to bunching affecting only mid vowels and not high ones, one could also suggest that the advancement or non-advancement of the tongue root has a smaller impact on F2 for the mid vowel. Further research on these issues is needed.

3.3 The feature [ATR] and the findings from Experiment 1

We begin by examining the properties of the assimilation process underlying Tricase metaphony. As mentioned earlier, ultrasound imaging reveals that the articulatory difference between mid-close and mid-open vowels involves the advancement of the tongue root with possible body displacement, affecting both front and back vowels. In fact, the tongue dorsum tends to be raised, although this gesture does not always reach statistical significance. As previously discussed, raising the tongue dorsum results from tongue bunching caused by the advancement of the tongue root. This advancement causes raising and anteriorization of [e] in the case of /ɛ/ → [e]/__[i], characterized by a decrease in F1 values and an increase in F2 values. Notably, the same forward movement of the tongue root does not cause anteriorization of [e] or [o] in the cases of /ɛ/ → [e]/__[u] and/ɔ/ → [o]/__[i]; conversely, consistent with Grimaldi (2003)'s findings, posteriorization of the allophone [o] in the case of /ɔ/ → [o]/__[u] has been observed. This result will be supported by data from Experiment 2: cf. Section 4, Table 4.

Overall, Southern Salentino varieties tend to align with Germanic languages from this perspective. In both the front and back vowel series, the vowels produced by the metaphonic process not only exhibit an advanced tongue root but also display tighter-than-neutral tongue curves. For front vowels, the tongue dorsum is higher and more fronted; for back vowels, the tongue dorsum is slightly higher and bunched further back.

4 Experiment 2: testing intra-speaker variation

The data collected from Experiment 1 revealed that the variation patterns seen in Southern Salentino are also evident among different speakers of the Tricase dialect. We designed Experiment 2 to check whether the same metaphonic patterns, along with their variation types, are present when three randomly selected speakers from the Tricasino community are asked to produce the list of words once, and then again an hour later. Although we recognize the limitation of this experiment, we limited our study to just three speakers because the research by Grimaldi (2003, 2009) and the findings from Experiment 1 provided strong consistent evidence of the inter-speaker variation in Southern Salentino and Tricasino metaphony. Only acoustic data were recorded.

4.1 Methods

4.1.1 Subjects, data acquisition, and statistical analysis

In a laboratory setting, we recorded the productions of three male speakers of the Tricase variety (average age 42.6, SD 3.6): V.A., R.S., and M.M. None of these speakers

Table 4: Results of the mixed-model analysis concerning the production of target vowels within words from the three Tricasino subjects. Adjusted *p*-values reported, single-step method. For each metaphonic context, significant metaphonic patterns for F1 and F2 are highlighted by asterisks: ***extremely significant, **very significant; *significant. Negative Estimate for F1 indicates that formants decrease in metaphonic context (i.e., target vowels are raised), positive Estimate for F2 indicate that formants increase in metaphonic context (i.e., target vowels are anteriorized), and negative Estimate for F2 indicate that formants decrease in metaphonic context (i.e., target vowels are posteriorized).

	F1				F2			
Metaphonic versus nonmetaphonic contexts	**Estimate**	**Std.Err.**	***Z* value**	**Pr(>|*z*|)**	**Estimate**	**Std.Err.**	***Z* value**	**Pr(>|*z*|)**
[e]/__[i] versus [ɛ]/__[ɛ,a]	−69.533	4.039	−17.217	<1e−05***	151.705	11.046	13.734	<1e−05***
[ɛ]/__[u] versus [ɛ]/__[ɛ,a]	−6.050	4.096	−1.477	0.68282	10.515	11.203	0.939	0.962159
[ɔ]/__[i] versus [ɔ]/__[ɛ,a]	−4.359	3.978	−1.096	0.91267	−18.126	10.922	−1.660	0.542003
[o]/__[u] versus [ɔ]/__[ɛ,a]	−39.809	4.096	−9.719	<1e−05***	−44.025	11.203	−3.930	0.000678***

were recruited for Experiment 1. All the subjects exhibited the same sociolinguistic characteristics as the speakers previously studied. In this experiment, the stimuli consisted of words embedded in the carrier phrase used earlier (cf. Section 2.1.1).

The stimuli included the target metaphonic vowels /ɛ/ and /ɔ/ in open and closed syllables. These were followed by trigger vowels [i], [u], and nontrigger vowels [ɛ, a]. The word stimuli matched those used in Experiment 1 (cf. Section 2.1.1). For each type of vowel, 10 stimuli were elicited. The peculiarity of this experiment is that the three speakers produced the same list of words once, and then again an hour later. No changes in register were observed or involved. Therefore, considering the three corner vowels (/i/, /a/, /u/) plus the six metaphonic and nonmetaphonic contexts for the mid-stressed vowels /ɛ/ and /ɔ/ (see (3)), 90 stimuli per subject were elicited, repeated twice, totaling 540 stimuli. The data collection followed the same procedures as in Experiment 1 (cf. Sections 2.1.1 and 2.1.2).

We fitted a linear mixed model to predict F1 and F2 separately with *TargetVowels*, *TriggerVowels*, and *WordRepetitions* as fixed factors. The model included *Subjects* as random effects. As for the previous analysis, *TriggerVowels* had three levels: namely, [i], [u] (the metaphonic triggers), and [e], [a] (the nonmetaphonic triggers). *TargetVowels* had two factors: the target vowels /ɛ/ and /ɔ/. *WordRepetitions* had two levels, *Word1* and *Word2*, which corresponded to the two repetitions of the experiment, 1 h apart. For both F1 and F2, we analyzed the multiple comparisons of means for the relevant contrasts.

4.1.2 Results

Both for F1 and F2, the likelihood ratio test revealed that the factor *WordRepetitions* was not statistically significant: χ^2 (12) = 19.463, p = 0.07794) for F1, and χ^2 (12) = 12.371, p = 0.4164) for F2. Thus, in Table 4, we reported the overall results obtained from the words produced by the three speakers twice (cf. Appendix 2, Experiment 2, for mean F1–F2 formant values per speaker in Hz, along with standard deviation, minimum, and maximum).[6]

The results for each subject investigated are represented in Figure 13.

In Figure 14, the vowels /i/, /a/, /u/, along with the allophonic variants of the mid-vowels /ɛ/ and /ɔ/, produced twice by the three speakers within words, are plotted in a two-dimensional F1–F2 Hz space using ellipses on the data. Although *WordRepetitions* was not statistically significant, the data in Figures 13 and 14 indicate

6 As for F1, the full model achieved conditional and marginal R^2 were 0.52 and 0.41, respectively. The model's intercept, corresponding to /ɛ/__[ɛ, a], was at 492.27 Hz (95% CI [471.08, 513.46], t(1658) = 45.57, p < .001). As for F2, conditional and marginal R^2 were 0.96 and 0.94, respectively. The model's intercept was at 1795.39 Hz (95% CI [1727.14, 1863.64], t(1656) = 51.60, p < .001.

that speakers tend not to have stable metaphonic patterns, so that assimilatory processes are characterized by variation (as we will discuss in the next sections).

4.2 Intra-speaker variation and previous findings

Experiment 2 shows that the metaphonic patterns for intra-speaker variation match earlier findings: i.e., both Grimaldi (2003), which recorded only one speaker per locality, and Experiment 1 (cf. Table 2, Figures 5–11), which analyzed different speakers from the same locality.

In particular, it has been confirmed once again that (1) [i] is a systematic trigger that primarily affects /ɛ/; (2) [u] is not a systematic trigger unless the target is /ɔ/. Again, the more common metaphonic patterns resulted in /ɛ/ → [e]/__[i] and /ɔ/ → [o]/__[u].

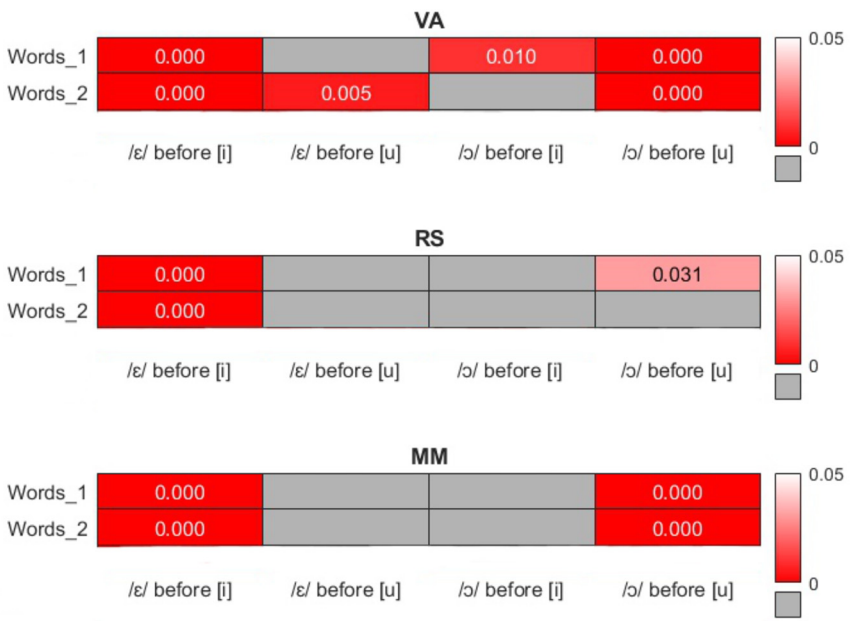


Figure 13: Different metaphonic action of unstressed [i] and [u] on the preceding stressed /ɛ/ and /ɔ/ vowels for speakers VA, RS, and MM. On the vertical axis: word repetitions. On the horizontal axis the metaphonic contexts /ɛ/ before [i], /ɛ/ before [u], /ɔ/ before [i], and /ɔ/ before [u]. The levels of statistical significance are represented in each column with shades ranging from red (extremely significant level) to white (significant level). Gray = not significant.

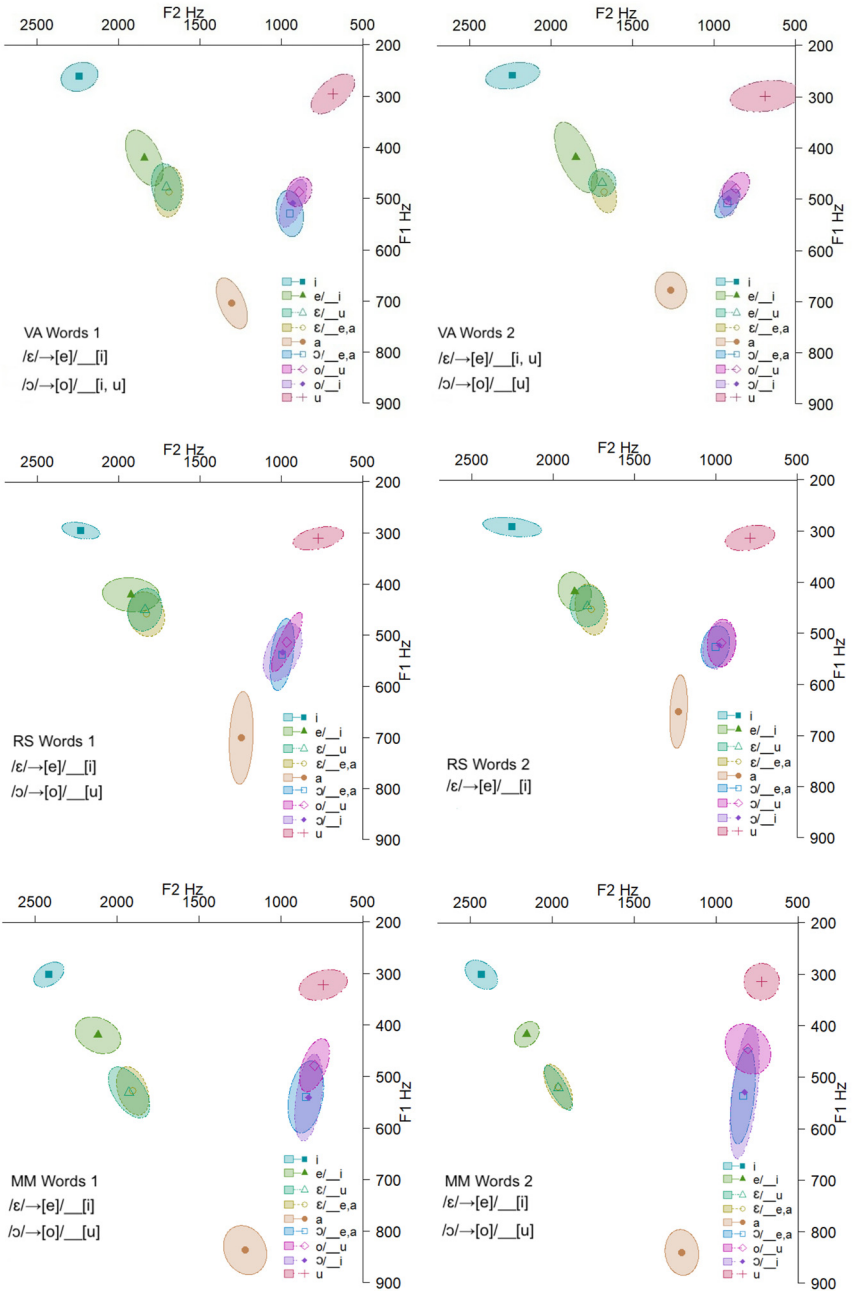


Figure 14: Scatter plots based on F1 and F2 Hz values of the vowels twice produced within words by subjects VA, RS, and MM. Significant metaphonic adjustments of mid vowels /ɛ/, /ɔ/ are shown. Each ellipse encompasses 68.8 % of data points for one vowel category.

Based on the data discussed above, [i] may occasionally also target /ɔ/, and [u] may occasionally target /ɛ/. Overall, our findings indicate that back vowels behave differently: it appears that back vowels hold a special status in the Southern Salentino system.

Another generalization concerns the effect of metaphony on the F2 of the target vowels. As already discussed, a strong impact is the increase of the F2 values for the /ɛ/ → [e]/__[i] pattern; thus, the allophonic variant [e] is raised and advanced in the acoustic space. The allophonic variant generated by [u] – the /ɛ/ → [e]/__[u] pattern – is generally raised but not advanced. Conversely, the metaphonic effect on the F2 values of the mid-back vowels is slightly different. While the allophone [o], triggered by final [i], is raised, the allophonic variant [o], due to the influence of final [u], is more raised and posteriorized, making it more external in the acoustic space. As in Ladefoged (1968) and Lindau (1979), our data suggest that changes in F2 values do not serve as a consistent cue for [+ATR] vowels (cf. Section 3.2.1).

However, beyond the generalizations identified, the data in Figures 1, 5, 6, 13, and 14 highlight that there is no stability in each speaker's production regarding the metaphonic outputs; in fact, they exhibit varying metaphonic patterns both at the inter- and intra-speaker level (and the same occurs when analyzing a randomly chosen speaker from the 36 localities investigated by Grimaldi 2003). Overall, these facts suggest that the Tricasino speakers have an unstable metaphonic system. Essentially, the metaphonic process is not fixed for any speakers.

5 The nature of variation in Salentino metaphony: diachronic and synchronic perspectives

5.1 Diachronic perspectives

Metaphonic processes affecting stressed mid-vowels followed by high vowels characterize all Southern Italian varieties (for general discussions of metaphony in Romance and Italo-Romance, see Calabrese 2011; Savoia 2015). Historical and comparative evidence shows that metaphonic alternations emerged in the early Middle Ages and became stable features of these varieties' phonology in later centuries (cf. Parlangeli 1953; Rohlfs 1966; Mancarella 1978; Maiden 1991, among others). In many cases, the neutralization or even disappearance of final vowels led to the morphologization of these processes, where suffixal high vowels realize inflectional

features like plural number or second person singular. Due to the neutralization or loss of these vowels, the only surface markers for these categories are the metaphonic alternants (see Calabrese 2016).

Let's now examine these processes in the varieties closest to Southern Salentino: specifically, Northern and Central Salentino. Comparative evidence from other dialects indicates that the metaphony system of Northern Salentino developed from a system similar to the *Neapolitan* type. Varieties of this kind are characterized by the common Romance seven-vowel system: /i, e, ɛ, a, ɔ, o, u/. In this system, mid-high vowels are consistently raised to high before a high vowel, while mid-low vowels in the same context are diphthongized. This causes alternations like in the examples ['peʃ:e]/['piʃ:i] "fish" singular/plural, ['pɛte]/['pjeti] "foot/feet," where the plural masculine form displays metaphonic effects. We accept the analysis proposed by Calabrese (1984, 1998) for this metaphony system. It involves the spreading of the high vowel feature [+high] onto the mid-stressed vowels; this explains the raising of the mid [+ATR] vowels to high. The [+high, −ATR] outcomes generated in the case of mid [−ATR] vowels are then diphthongized (see footnote below).[7]

7 Calabrese (1984, 1998) proposed that the diphthongization observed in the case of [-ATR] mid vowels [ɛ, ɔ] results from a repair process affecting the metaphonic output vowels [I] and [U]. In Calabrese's analysis, these vowels are illicit because of the independently motivated constraint * [+high, -ATR] forbidding the appearance of these features in the same feature bundle. The diphthongization then results from a fission process that splits the disallowed configuration [+high, -ATR] into two feature bundles: one containing [+high] and the other containing [-ATR], forming the diphthongs [iɛ], [uɔ] ([iɛ́/jɛ́], [uɔ́/wɔ́]) or [íɛ/íə], [úɔ/úə] after stress assignment and other prosodic, syllabic, and segmental adjustments (see Calabrese (1984, 1998, 1995, 2025) for further details and discussion of other repairs found in these disallowed vowels).

It is worth noting at this point that the complexity of the experimental design of the research behind the study presented in this article required us to focus solely on the mid-vowel raising triggered by final high vowels. Southern Salentino varieties, however, are also characterized by another process of metaphonic assimilation affecting stressed high vowels before nonhigh ones (Grimaldi 2003). In this case, the high vowel diphthongizes before the lower vowels.

(i) /i, u/→[iə, uə]/___/ɛ, a/

(ii)	a.	[pa'riti]	[pa'rjətɛ]	"wall-pl/sg"
		[kan'tsuni]	[kan'tsənɛ]	"song-pl/sg"
	b.	['minu]/['mini]	['miəna]	"throw.away-Pres.1sg/2sg/3sg"
		['vinnu]/['vinni]	['viənnɛ]	"sell-Pres.1sg/2sg/3sg"
		['kusu]/['kusi]	['kuəsɛ]	"sew-Pres.1sg/2sg/3sg"
	c.	['kinu]/['kini]	['kiəna]/['kiənɛ]	"full- m.sg/m.pl/ f.sg./f.pl"
		['russu]/['russi]	['ruəssa/'ruəssɛ]	"red- m.sg/m.pl/ f.sg./f.pl"

We know from Section 3 that the nonhigh vowels /ɛ, a/ are [-ATR]. The process in (i) can then be formulated as a process where the stressed high vowels assimilate the feature [-ATR] of the following vowels. But then this process has the same structural description as the metaphonic process discussed in the text, where stressed mid-vowels assimilated the feature [+ATR] of subsequent

Eventually, the distinction between mid-high and mid-low vowels was lost, evolving into a five-vowel system /i, ɛ, a, ɔ, u/. This change led to the lexicalization of the metaphonic alternants, as seen in the dialect of Francavilla Fontana: ['pɛʃːi]/['piʃːi] for "fish" singular/plural, and ['pɛti]/['pjeti] for "foot/feet" singular/plural. Here, the neutralization of the final unstressed vowel into high vowels also causes the loss of singular/plural opposition (cf. Calabrese and Grimaldi, in press). The Central Salentino vowel system differs from the Northern one, as mid-high vowels have merged with the high vowels across the board, so that alternations only occur with mid-low vowels, as in Campi: ['piʃːɛ]/['piʃːi] for "fish" singular/plural, and ['pɛti]/['pjeti] for "foot/feet."

Let us now turn to Southern Salentino varieties. Note that they share with the Central varieties the merging of mid-high vowels with high vowels. Traditional descriptions of these varieties state that they are not characterized by metaphonic phenomena (Mancarella 1998; Parlangeli 1953; Rohlfs 1966; Stehl 1988). In fact, a careful phonetician like Gerhald Rohlfs does not report any metaphonic alternations for these varieties in his fieldwork for the *Atlante Linguistico ed Etnografico dell'Italia e della Svizzera Meridionale* (AIS) during the 1920s, with the exception of a single example of metaphonic raising for the Southern Salentino variety of Salve (e.g., ['pɛte/'peti] "foot/feet"). Even 40 years later, Luciano Graziuso, working for the *Carta dei Dialetti Italiani* (CDI), finds only one example of metaphonic raising in the Southern Salentino variety of Tiggiano, for e.g., [ʃɛnkaˈrɛɖːa]/[ʃɛnkaˈrɛɖːɛ] fem., [ʃɛnkaˈreɖːu]/[ʃɛnkaˈreɖːi] masc., "calf/calves."[8]

To explain the inconsistency between the traditional description of Southern Salentino varieties and the findings of this work and Grimaldi (2003), we suggest that the spread of metaphonic alternations in Southern Salentino varieties is a relatively

---

vowels. It is reasonable to conclude that both processes can be unified as an assimilation based on the feature [αATR], using the traditional SPE format for clarity.

(iii) [+syllabic, +stressed, -low] →[αATR]/ __ [αATR].

Applying this process to high vowels in (ii) produces [+high, -ATR] vowels. Calabrese (2025) suggests that the diphthongization observed here results from the same fission process that affects the metaphonic outputs of the [-ATR] mid vowels [ɛ, ɔ] in classical Italo-Romance metaphony. Therefore, the [+high, -ATR] [I] and [U], which are the outcomes of (i), are corrected through fission that splits their disallowed [+high, -ATR] configuration into two feature bundles: one containing [+high] and the other [-ATR]; assignment of prosodic prominence to the first vocoid of the fissioned configuration and segmental reduction of the second element generate *[iə, uə]*. Thus, the same repair operation is involved in two quite different historically independent phenomena.

8 The data collected in 1964 for the Nuovo Atlante Fonetico Pugliese by Melillo (1986) showed the presence of three metaphonic forms, this time in Gallipoli and Castrignano del Capo (see Figures 1 and 2). The author attributed the forms to idiosyncratic variability among the speakers, rather than to specific phenomena of these dialects: i.e., ['*servi*] "domestics," [*'bːonu*] "good" (adjective, singular, masculine), [*'morju*] "I die."

recent development. This is supported by the interspeaker and intra-speaker variation we observe in the varieties, which will be discussed in more detail in the next section. We also believe that it developed independently of the classical metaphony found in the more northern Italo-Romance varieties, most likely in the last century, making it significantly more recent than the classical metaphony, which dates to the early Middle Ages (Parlangeli 1953; Rohlfs 1966; Mancarella 1978; Maiden 1991, among others).[9]

Recent research by Barnes (2019) and Greca et al. (2024) uncovers additional cases of variation in Romance metaphonic systems. In both instances, these systems have been known since the early 1900s: the Calabrian and Lucanian varieties studied by Greca et al. (2024) were thoroughly described by Lausberg (1939); the Asturian varieties examined by Barnes (2019) were documented by Menéndez Pidal (1952) and Rodríguez Castellano (1952). Both Greca et al. (2024) and Barnes (2019) demonstrate that the systems previously studied are undergoing significant changes (in the Calabrian and Lucanian varieties) or are in decline (in the Asturian varieties). Consequently, in both cases, the variation results from the breakdown of older, documented systems. The situation in Southern Salentino is quite different, where, as previously mentioned, no metaphonic changes were recorded in earlier studies (Mancarella 1998; Parlangeli 1953; Rohlfs 1966; Stehl 1988). Southern Salentino metaphony appears to be a recent development, and its varying patterns are likely due to that, as discussed in the next section. The common factor across all these systems is that variation stems from the lack of established patterns and the pursuit of new ones. It would be interesting to explore whether common trends can be identified across all of them.

5.2 Synchronic perspectives

A key issue to address is the nature of the variation we observe in Southern Salentino. Linguistic variation can arise from many sources and can be multidimensional. One possibility is sociolinguistic diversity: speakers from different social backgrounds speak differently, and all speakers vary in speech style and register. However, the variation we see in Tricase cannot be explained by sociolinguistic differences. Initially, we were confused by the variation and examined the sociolinguistic and parental backgrounds of all speakers in our study, but we could not link any social factor to their different metaphonic patterns. Furthermore, no register differences could be reasonably linked to the observed patterns. Additionally, the age and education level of the speakers in Grimaldi's (2003) study and our own do not account for the metaphonic variations.

9 A discussion of the possible relation, and differences, between classical metaphony and Southern Salentino metaphony is not possible here due to space constraints and is given in Calabrese and Grimaldi (in press).

Specifically, the subjects in Grimaldi's (2003) research averaged 70 years old and were illiterate or had only primary education, while the speaker studied by Grimaldi et al. (2010) was 54 years old with a college degree. The participants in Experiments 1 and 2 were, on average, 21 (university students) and 42 years old (college degree), respectively. Therefore, the evidence, along with the findings discussed above, strongly indicates that the variation patterns are not influenced by sociolinguistic factors. This is confirmed by Experiment 2, which shows that the same variation can occur within the same speaker, suggesting a variable realization that lacks social meaning.

Variability can also occur at the acoustic and articulatory levels. For example, vowels vary in their realization. As Peterson and Barney (1952) demonstrated, a vowel cannot be defined as a single articulatory point or a specific acoustic realization, but rather as a region within articulatory and acoustic space. Therefore, measurements of a speaker producing a particular vowel may show significant scatter within this range and may even fall outside it. However, this variation is essentially random and does not explain the presence of clearly defined (though still variable) metaphonic patterns across different speakers or even within the same speaker.

A third factor in variability is simple optionality: some phonological processes may or may not occur under the same specific circumstances. However, in the case of Tricasino, and probably in other Southern Salentino varieties, the different patterns we see are quite different from each other, as shown in (7) below; the optionality of a single process cannot explain that variability. It is necessary to assume that many *different* processes can be applied optionally. Therefore, the reason for the variation among these processes remains unresolved. Simple rule optionality cannot fully account for their differences.

Another potential source of variation can be found in emergent gradient phonetic processes or developing phonological phenomena that have not yet reached normative status across members of a social group or community. First, variation arises due to acoustic, perceptual, and articulatory constraints on speech. As a result, phonetic entities can be pronounced differently depending on the environment. These variable patterns are universal and fall outside human cognitive control. Such gradient variable patterns may become phonologized. In phonologization, a variable pattern caused by extragrammatical factors is reanalyzed by speakers as involving both a new language-specific generalization and the formation of stable phonological categories. Consequently, this generalization becomes cognitively controlled and internalized in the grammar (Bermúdez-Otero 2013; Bermúdez-Otero and Trousdale 2012; Kiparsky 2006).

We can say that a variable pattern is reinterpreted as a generalization over discrete categories in phonological representations, such as features or other specific configurations (here we will not consider the conditions under which this occurs). Therefore, the phonologization of a particular pattern leads to phonological innovation. Some innovations spread, while others do not. Phonological change happens as it spreads from the innovators to other members of a social group, where it is

accepted by early adopters and then diffuses to more members. During this diffusion process, natural variation occurs. Over time, the variations become structured, and the variants may gain social meaning. If fully successful, it will become a normative phonological aspect of the community or social group (Labov 2001, 2010, 2014a, 2014b; Bermudez-Otero 2020). We suggest that this final step has not yet fully taken place in the case of Southern Salentino metaphony.

First of all, let's consider the possibility that this study does not reveal the emergence of new variation but instead captures universal V–C–V coarticulatory patterns that might always be characteristic of vowel sequences in five-vowel systems. If this were true, these patterns should be universal, at least in five-vowel languages. The fact that some Southern Salentino varieties seem to lack any metaphonic alternations entirely rules out this possibility. The processes are language-specific, so speakers must learn the phonological rules governing the phenomenon. Therefore, they must be under cognitive control.

The fact that the process is under cognitive control is also supported by our behavioral and neurophysiological investigations (Miglietta et al. 2013). In this work, we examined whether allophonic variants [e], [o] and the phonemes /ɛ/ and /ɔ/ are processed differently by the speakers' auditory system. The behavioral and electrophysiological responses from 12 Tricase speakers suggested that both allophones and phonemes are equally categorized during early speech processing and are encoded in memory representations. In this case, the neural computations involving the mapping of auditory inputs into higher perceptual representations seem "sensitive" to the contrastive or noncontrastive status of sounds, as determined by the listeners' knowledge of the phonological system. Based on these results, we argued that Southern Salentino metaphony must have a cognitive basis. It follows that Southern Salentino metaphony has, at the very least, undergone phonologization. It is a language-specific and cognitively controlled generalization learned by speakers of Southern Salentino varieties.

This generalization is over discrete categories in the phonetic surface, which realize phonological representations. As previously noted by Bermudez-Otero and Trousdale (2012), the stabilization of a gradient phonetic process into such a generalization is demonstrated by a consistent bimodal distribution of output tokens from this process (see also Scobbie 2005). This type of bimodal distribution is precisely observed in the outputs of Southern Salentino metaphony, as shown in Figure 12. Examining the significant harmony effects on the F1 Hz values, it is evident that both unstressed [i] and [u] harmonize with [ɛ] and [ɔ], producing the [e] and [o] allophones. In Figure 12, it is easy to see how the allophonic outputs generated by metaphonic assimilation display a clear bimodal distribution, where discrete allophonic categories reflect the application of a phonological rule (as discussed in Section 3.1).

This clearly supports an analysis of the process as operating on categorial distinctions. We can, therefore, assume that Southern Salentino metaphony is a phonologically

stabilized process spreading categorial features across segments. Additionally, we suggest that in the case of Southern Salentino metaphony, we are dealing with a process that is phonologically stabilized but not yet fully normative across social groups and communities. Speakers have learned the metaphony rule but still lack a norm on how it should function. This allows for the variation as accounted for below.

6 Phonological analysis

We now need to address the issue of the different metaphonic patterns. What are the interacting parameters and constraints that control the spreading of the features generating the variation, and how can a phonological model capture this process?

First of all, it is necessary to identify the properties of the assimilation process underlying Southern Salentino metaphony. As previously discussed, ultrasound imaging of the vocal tract shows that in this variety, the articulatory difference between mid-high and mid-low vowels – where mid-high vowels acoustically have a lower F1 and a peripheral position for F2 – involves tongue root advancement. Both front and back metaphonic vowels also display tongue body bunching. For front vowels, the tongue body is bunched forward, while for back vowels, it is bunched backward. In both cases, the metaphonic mid vowels are higher than nonmetaphonic ones. Interestingly, this effect seems to be more pronounced when the trigger and the target vowel are on the same front/back axis.

We can assume that the underlying vowel system in Southern Salentino in (5) has the feature assignments in (6):

(5)
i u
ɛ ɔ
a

(6)

	i	ɛ	a	ɔ	u
High	+	−	−	−	+
Low	−	−	+	−	−
Back	−	−	+	+	+
ATR	+	−	−	−	+

We can now proceed with an account of the variation observed in Southern Salentino metaphony. We will employ Calabrese's (2005, 2009, 2019) theoretical model, which incorporates both rules and negative constraints within a classical derivational framework (see the quoted works for supporting arguments).

As mentioned earlier, the preferred target of this process is [ɛ]. In many varieties, it is the only target of the phenomenon. Back [ɔ] is never the sole target unless it

is followed by [u]. Therefore, some speakers only have /ɛ/ → [e]/__/i/ or /ɛ/ → [e]/__[i, u], but there are no speakers who only have /ɔ/ → [o]/__/i/ or /ɔ/ → [o]/__[i, u].

At the same time, [i] is the most common trigger for Southern Salentino metaphony. The /ɛ/ → [e]/__/i/ pattern generally shows very significant statistical levels. Additionally, [i] is often the only trigger, whereas [u] is never involved unless /ɔ/ is the sole target. No variety shows patterns like /ɛ/ → [e]/__[u] or /ɛ, ɔ/ → [e, o]/__/u as the sole metaphonic processes. This creates a clear asymmetry between final [u] and final [i] in triggering the phenomenon.

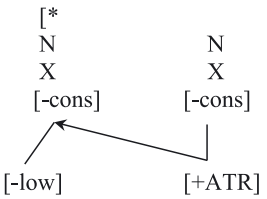
Final [u] is preferably not a trigger for metaphony, and stressed [ɔ] is ideally not a target for metaphony. The only exception is the pattern [ɔ] → [o]/__[u], which, along with /ɛ/ → [e]/__[i], is also characterized by a very significant statistical level. Note that harmony systems where a target segment assimilates a feature from a trigger segment only when they share a feature are well documented (Cole and Trigo 1988; Nevins 2010; Steriade 1981). These are known as parasitic harmony systems. A well-known example is Yokuts rounding harmony: /i/ → [u]/__[u], /a/ → [o]__[o], where vowels are rounded only when they occur before rounded vowels of the same height. We will call the Southern Salentino pattern /ɛ/ → [e]/__[i], /ɔ/ → [o]/__[u] a back-based parasitic metaphony.

The patterns to account for are listed in (7) for ease of reference:

(7) a. /ɛ/ → [e]/ __ [i] (Area A, Tricase 1Exp M.B, Tricase 2Exp RS)
b. /ɛ/ → [e]/__[i, u] (Area B)
c. /ɛ, ɔ/ → [e, o]/__[i] (Area C)
d. /ɛ/ → [e]/__[i], /ɔ/ → [o]/__[u] (Area D, Tricase 1Exp CR, Tricase 2Exp MM RS, MM)
e. /ɛ/ → [e]/__[i, u], /ɔ / → [o]/__ [u] (Area E, Tricase 2Exp VA)
f. /ɛ/ → [e]/__[i], [ɔ] → [o]/__[i, u] (Tricase 1Exp GC, GE)
g. /ɛ, ɔ/ → [e, o]/__[i, u] (Area F, Tricase 1Exp LG, Tricase 2Exp VA)

We suggest that the different metaphonic alternations seen in Southern Salentino involve processes of [+ATR] assimilation. In the most general process described in (2), both [i] and [u] can trigger metaphony for both mid vowels. This process, shown in (8a), can be accounted for by the rule in (8b) (where [* indicates that the vowel carries main stress, N = syllabic nucleus, X = skeletal position):

(8) a. /ɛ, ɔ/ → [e, o]/__[i, u] (cf. (7g))
b.



The issue is to account for the variation we observe across different local varieties, within the same variety, and among individual speakers. As mentioned earlier, note that in some cases, [u] is not a possible trigger, and in other cases, [ɔ] is not a possible target. The special behavior of back vowels can be explained as follows: Remember the conclusion from Section 3.2.2, where, in producing [+ATR] back vowels, speakers must suppress the natural tendency to front them. This suppression requirement makes the configuration [+ATR, +back] articulatorily complex, and thus phonologically marked. The marking statement in (9) captures this complexity:

(9) *[+back, +ATR]

If this constraint is active (high ranked in OT terms), back vowels must be [−ATR]. If [u] is [−ATR], it cannot be a trigger of (8); at the same time, application of (8) to [ɔ] is blocked from being a target of [i] for the same reason. Metaphony in this case can target only /ɛ/ before /i/, as in (10):

(10) /ɛ/ → [e]/ __ [i] (cf. 7a)

At the same time, our data suggest that high back vowels and nonhigh ones behave differently regarding the feature [ATR]: the former are often nontriggers, and the latter are not targets of the metaphony process. We hypothesize that this difference arises from a parametric distinction in the constraint in (9). Tongue root advancement may interact with tongue body raising or nonraising, creating articulatory configurations of varying complexity that can be sensitive to different constraints. Therefore, we assume the constraint in (9) may be sensitive to different settings of the feature [high], as shown below.

(11) a. *[+back, +ATR, +high]
b. *[+back, +ATR, -high]

The combined effect of the constraints in (11a) and (11b) would parallel what occurs with (9). If only one of them is active (a ranking difference in OT terms), then the following situations occur. When only the constraint in (11a) is active, the high vowel must be [−ATR] and cannot serve as a trigger; however, the process can target mid-low /ɔ/. The situation would then be as shown in (12):

(12) /ɛ, ɔ/ → [e, o]/__[i] (cf. (7c)

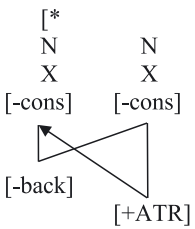
If the constraint in (11b) is active but the one in (11a) is not, [u] can act as a trigger but /ɔ/ cannot be a target, so we would have (13):

(13) /ɛ/ → [e]/__[i, u] (cf. (7b))

Thus, the general rule in (8), when combined with the constraints in (11), could explain some of the variability observed in Southern Salentino metaphony. However, we still

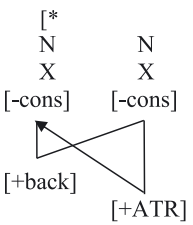
need to explain parasitic metaphony. In this regard, we can revisit the assimilatory pattern in (10): /ɛ/ → [e]/ __ [i]. This pattern is the most statistically stable one across different systems and can be seen as the simplest pattern from a markedness perspective, as it fully respects the constraints in (11). One might also suggest that this is the historically most fundamental pattern. Let's assume it can be analyzed as involving a linked [-back], as expected in a nonlinear framework, as in (14):

(14)



One can assume that this analysis might also result in a reanalysis of the metaphonic process triggered by back vowels as being parasitic on the feature [+back], as in (15):

(15)



Support for (14) or (15) comes from the fact that either can apply alongside the more general (8). Being more specific, they take precedence over (8) and override it in relevant cases due to the elsewhere principle. When (14) applies with (8), the situation is as shown in (16):

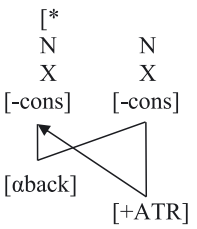
(16) /ɛ/ → [e]/__[i] (by (14)) & /ɛ, ɔ / → [e, o]/__ [u] (by elsewhere application of (8)) (cf. (7f))

If (15) applies along with (8), we get the situation in (17):

(17) [ɔ] → [o]/__[u] (by (15)) & /ɛ, ɔ/ → [e, o]/__[i] (by elsewhere application of (8)) (cf. (7e))

If (14) and (15) apply together, as represented in (18), we would get the situation in (19). This can be seen as a general instance of parasitic metaphony. This seems to be the most frequently observed process among Tricasino speakers and in the Southern Salentino varieties.

(18)



(19) /ɛ/ → [e]/__[i], /ɔ/ → [o]/__[u] (cf. (7d))

There may also be concomitant articulatory and acoustic factors that favor the reanalysis just proposed. Notice, in fact, the effects of metaphonic assimilations on F2 values: a significant effect is the increase in F2 for the /ɛ/ → [e]/__[i] pattern; the allophonic variant [e] is raised and moved forward in the acoustic space. Conversely, for mid-back vowels before [u], F2 decreases, making the vowel acoustically more posterior and thus more external in the acoustic space than the nonassimilated [ɔ].

The allophonic variants [e], [o] also have two unequal levels of height, linked to differences in F1 values (see Figure 12). Their height depends on the trigger that generates metaphonic assimilation: on the front axis, [e] before [i] is higher than [e] before [u], while on the back axis, [o] before [u] is higher than [o] before [i].

We proposed that these articulatory behaviors result from the tongue bunching that characterizes [+ATR] vowels in these Italo-Romance varieties. The different behavior of metaphonic target vowels before triggers of the same backness may also be linked to a synergistic interaction between the bunching gesture in the trigger and the target. The target's bunching may increase as a consequence. This explains the acoustic effect described earlier: that is, how the [i], [u] triggers create two asymmetrical levels of height in the allophonic variants [e], [o] (see Section 3.3). We believe these acoustic-articulatory patterns encouraged the reanalysis proposed earlier in (18).

Considering the statistical dominance of parasitic metaphony among Southern Salentino varieties, we also propose that parasitic harmony is now the main phonological innovation spreading among Southern Salentino speakers. We thus have an account of all the metaphony patterns we observed in these varieties, along with their variations.

7 Conclusions and further remarks

Unlike other widely studied harmony processes, Southern Salentino metaphony is marked by instability: its patterns show variation both between speakers and within individual speakers. Our data suggest that this variation is not due to sociolinguistic factors (see Section 5.2), as it cannot be linked to any social variables. Instead, we believe that we are observing an ongoing linguistic change that has not yet fully

become a part of the phonological system in these communities. We hypothesize that the Tricase situation – likely the most common across Southern Salentino – indicates that none of the metaphony variants have gained socially accepted status. As a result, the process remains only partially grammaticalized within the linguistic system. Learners of a given speech variety – that of Tricase, in this case – have acquired the knowledge that a harmonic assimilation process spreads the feature [+ATR] from the final high vowels to the preceding stressed mid vowels. This process could be parasitic metaphony or a more general process as described in (8). Both scenarios involve interaction with the active constraints in (11), as previously discussed. However, without a fully established grammatical norm, speakers are still exploring how this process functions. We propose that this exploration causes the variation observed. If our hypothesis is correct, it also implies that Southern Salentino metaphony is a recent development (*contrary to* Loporcaro 2016, who suggested it was active already in early medieval times). Further research is necessary to determine whether this variation exists across all Southern Salentino communities or if some varieties have reached a stable grammatical state, with norms fully established.

Acknowledgments: We want to thank Francesco Sigona for his invaluable support in creating figures and conducting statistical analyses of the data. We are also grateful to Walter Shaw and three anonymous reviewers for their comments, which helped us improve the manuscript and the interpretation of the data. All errors are our own.

Appendix 1

List of stimuli produced by subjects in the carrier phrase *Ieu ticu* ___*moi* “I say ___now”

/i/

1. /'fili/ “threads”
2. /'pili/ “hairs”
3. /'mila/ “apple”
4. /'vivu/ “I live”
5. /'friɖ:u/ “cold” (sg. m.)
6. /'sik:a/ “dry” (sg. f.)
7. /'vinti/ “twenty”
8. /'tiʃatu/ “finger”
9. /'mintɛ/ “he puts”
10. /'sitɛ/ “thirst”

/ɛ/ before /i/

1. /ˈtʃɛfali/ “grey mullets”
2. /ˈlɛpri/ “hares”
3. /ˈlːɛvali/ “remove them”
4. /ˈprɛvati/ “priests”
5. /ˈfrɛvi/ “fevers”
6. /ˈlɛtːi/ “beds”
7. /ˈbːɛɖːi/ “nice” (pl. m.)
8. /ˈspɛtːi/ “you wait”
9. /ˈdɛnti/ “teeth”
10. /ˈlːɛvi/ “you remove”

/ɛ/ before /u/

1. /ˈtʃɛfalu/ “grey mullet”
2. /ˈlːɛvu/ “I remove”
3. /ˈbːɛɖːu/ “nice” (sg. m.)
4. /ˈletːu/ “bed”
5. /ˈspɛtːu/ “I wait”
6. /ˈpɛrdu/ “I lose”
7. /ˈsɛntu/ “I feel”
8. /ˈʃɛlu/ “freeze”
9. /ˈlɛgːu/ “I read”

/ɛ/ before /ɛ, a/

1. /ˈfrɛvɛ/ “fever”
2. /ˈlɛprɛ/ “hare”
3. /ˈpɛska/ “peach”
4. /ˈprɛvatɛ/ “priest”
5. /ˈpɛrta/ “opened” (sg. f.)
6. /ˈlɛtːɛ/ “read” (pl. f.)
7. /ˈspɛtːa/ “you wait”
8. /ˈbɛɖːa/ “nice” (sg. f.)
9. /ˈdɛntɛ/ “tooth”
10. /ˈlːɛva/ “he removes”

/a/

1. /ˈaku/ “needle”
2. /ˈapu/ “bee”
3. /ˈkasa/ “home”
4. /ˈfatːu/ “fact”

5. /ˈpasta/ “pasta”
6. /ˈtasːa/ “tax”
7. /ˈkapu/ “head”
8. /ˈʧaˈrasa/ “cherry”
9. /ˈfatsːu/ “I do”
10. /ˈfamɛ/ “hunger”

/ɔ/ before /ɛ, a/

1. /ˈzːɔpːɛ/ “lame” (pl. f.)
2. /ˈprɔva/ “proof”
3. /ˈzːɔpːa/ “lame” (sg. f.)
4. /ˈnɔvɛ/ “nine”
5. /ˈnɔva/ “new” (sg. f.)
6. /trɔva/ “he finds”
7. /ˈtɔkːa/ “he touches”
8. /ˈrɔsɛ/ “roses”
9. /ˈnɔnːa/ “grandmother”
10. /ˈnɔnːɛ/ “grandmothers”

/ɔ/ before /i/

1. /ˈzːɔpːi/ “lame” (pl. m.)
2. /ˈkɔfani/ “clay containers to do the laundry”
3. /ˈprɔvi/ “you try”
4. /ˈtɔsːi/ “you cough”
5. /ˈmɔvili/ “move them”
6. /ˈnɔvi/ “new” (pl. m.)
7. /ˈtrɔvi/ “you find”
8. /ˈtɔcːi/ “you touch”
9. /kaˈrɔfani/ “carnations”
10. /ˈnɔnni/ “grandfathers”

/ɔ/ before /u/

1. /ˈzːɔpːu/ “lame” (sg. m.)
2. /ˈkɔfanu/ “clay container to do the laundry”
3. /ˈprɔvu/ “I try”
4. /ˈtɔsːu/ “I cough”
5. /ˈnɔvu/ “new” (sg. m.)
6. /kaˈrɔfanu/ “carnations”
7. /ˈtrɔvu/ “I find”

8. /ˈtɔkːu/ “I touch”
9. /ˈnɔnːu/ “grandfather”
10. /ˈpɔrtu/ “I bring”

/u/

1. /ˈukːa/ “mouth”
2. /ˈtutʃɛ/ “sweet” (sg. f.)
3. /ˈfunːu/ “farmland”
4. /ˈlupu/ “wolf”
5. /ˈmuti/ “speech-impaired” (pl. m.)
6. /ˈputsːa/ “smell”
7. /ˈrusːi/ “red” (pl. m.)
8. /ˈrumpi/ “you break”
9. /ˈsusu/ “upon”
10. /ˈlune/ “moons”

Appendix 2

F1 and F2 values in Hz

Experiment 1

Tables 5–10: Mean formant values F1–F2 in Hz of the Tricase vowels produced by the six speakers investigated. DS = standard deviation; Min = minimum; Max = maximum.

Table 5: MB female.

Vowels	Hz	/i/	e/__i	e/__u	e/__e,a	/a/	o/__e,a	o/__u	o/__i	/u/
Mean	F1	333	530	643	645	1,023	641	624	636	398
	F2	2,728	2,312	2,013	2,062	1,542	1,155	1,087	1,082	879
DS	F1	10	47	16	24	57	32	31	58	50
	F2	58	101	77	105	117	112	65	118	71
Min	F1	321	482	618	609	921	576	545	519	319
	F2	2,666	2,185	1,894	1,919	1,380	949	992	868	796
Max	F1	350	609	665	677	1,157	686	655	741	483
	F2	2,832	2,466	2,086	2,290	1,713	1,315	1,223	1,256	1,027

Table 6: CR female.

Vowels	Hz	/i/	e/__i	e/__u	e/__e,a	/a/	o/__e,a	o/__u	o/__i	/u/
Mean	F1	385	448	634	635	829	644	598	635	427
	F2	2,642	2,343	1,999	1,978	1,436	1,203	1,177	1,180	993
DS	F1	30	23	39	42	24	13	39	31	19
	F2	57	107	194	148	103	89	66	58	89
Min	F1	341	413	559	543	800	626	534	563	412
	F2	2,507	2,217	1,804	1,704	1,270	1,031	1,069	1,090	868
Max	F1	435	485	699	710	855	670	642	674	464
	F2	2,700	2,514	2,263	2,183	1,552	1,333	1,245	1,275	1,112

Table 7: MM male.

Vowels	Hz	/i/	e/__i	e/__u	e/__e,a	/a/	o/__e,a	o/__u	o/__i	/u/
Mean	F1	296	475	513	526	861	576	498	558	381
	F2	2,325	2,071	1,944	1,965	1,459	1,029	1,038	1,054	893
DS	F1	27	30	26	62	34	51	51	44	24
	F2	47	88	64	77	80	51	81	60	75
Min	F1	259	429	480	455	803	497	445	494	349
	F2	2,243	1,878	1,820	1,844	1,348	952	948	954	811
Max	F1	332	524	554	642	904	646	619	632	434
	F2	2,396	2,158	2,031	2,083	1,541	1,112	1,183	1,150	1,024

Table 8: GC male.

Vowels	Hz	/i/	e/__i	e/__u	e/__e,a	/a/	o/__e,a	o/__u	o/__i	/u/
Mean	F1	287	415	508	522	730	517	464	494	321
	F2	2,160	2,025	1,805	1,785	1,298	986	911	948	802
DS	F1	36	10	18	23	23	13	24	14	27
	F2	98	103	88	60	65	76	57	33	43
Min	F1	249	400	489	475	690	496	428	474	280
	F2	2,063	1,886	1,668	1,680	1,215	889	818	914	764
Max	F1	368	432	539	559	767	534	500	518	394
	F2	2,414	2,175	1,919	1,903	1,418	1,098	994	1,025	889

Table 9: LG male.

Vowels	Hz	/i/	e/__i	e/__u	e/__e,a	/a/	o/__e,a	o/__u	o/__i	/u/
Mean	F1	288	413	457	503	737	517	471	489	329
	F2	2,125	1,948	1,842	1,767	1,266	1,004	941	972	805
DS	F1	13	10	30	35	19	15	26	32	48
	F2	84	70	73	66	72	36	37	55	78
Min	F1	273	390	424	445	702	481	439	433	290
	F2	1,952	1,838	1,755	1,679	1,178	952	888	810	701
Max	F1	316	423	511	546	769	532	516	526	422
	F2	2,267	2,044	1,990	1,892	1,388	1,065	1,005	1,028	942

Table 10: GE male.

Vowels	Hz	/i/	e/__i	e/__u	e/__e,a	/a/	o/__e,a	o/__u	o/__i	/u/
Mean	F1	255	448	528	549	683	544	483	518	324
	F2	2,077	1,968	1,697	1,691	1,188	1,020	938	1,000	764
DS	F1	6	21	19	9	47	13	24	25	14
	F2	57	92	49	69	25	59	75	65	47
Min	F1	243	405	499	530	624	528	450	486	310
	F2	1,976	1,828	1,640	1,549	1,159	890	831	906	695
Max	F1	264	466	556	559	780	570	520	547	354
	F2	2,185	2,076	1,772	1,826	1,243	1,094	1,046	1,129	872

Experiment 2

Tables 11–16: Mean formant values F1-F2 in Hz of the Tricase vowels produced within words twice repeated by the three speakers investigated. DS = standard deviation; Min = minimum; Max = maximum.

Table 11: VA words_1.

Vowels	Hz	/i/	e/__i	e/__u	e/__/e,a	/a/	o/__e,a	o/__u	o/__i	/u/
Mean	F1	262	421	478	487	704	529	487	509	295
	F2	2,240	1,843	1,707	1,692	1,306	950	893	931	686
DS	F1	17	34	29	32	30	29	18	30	24
	F2	69	73	58	56	58	53	49	53	82
Min	F1	234	357	408	413	650	472	458	444	263
	F2	2,110	1,674	1,597	1,609	1,202	811	788	836	533
Max	F1	289	523	553	582	753	629	542	589	345
	F2	2,379	2,004	1,824	1,847	1,382	1,014	984	1,036	834

Table 12: VA words_2.

Vowels	Hz	/i/	e/__i	e/__u	e/__/e,a	/a/	o/__e,a	/o/__u	/o/__i	/u/
Mean	F1	259	418	468	486	678	508	479	499	299
	F2	2,236	1,849	1,687	1,677	1,266	920	868	912	688
DS	F1	16	43	17	26	22	18	20	22	19
	F2	102	83	52	50	58	49	53	38	132
Min	F1	245	331	445	439	642	455	440	455	272
	F2	2,099	1,668	1,623	1,586	1,178	813	758	830	507
Max	F1	307	534	518	552	718	558	521	547	334
	F2	2,399	2,006	1,857	1,798	1,362	1,066	967	980	978

Table 13: RS words_1.

Vowels	Hz	/i/	e/__i	e/__u	e/__/e,a	/a/	o/__e,a	/o/__u	/o/__i	/u/
Mean	F1	296	421	450	459	701	538	513	534	311
	F2	2,233	1,925	1,840	1,832	1,248	997	968	993	775
DS	F1	10	21	26	28	55	45	37	36	14
	F2	71	110	66	72	45	47	60	75	95
Min	F1	275	352	401	409	622	411	428	468	291
	F2	2,106	1,797	1,719	1,673	1,132	860	832	869	623
Max	F1	318	462	528	523	817	635	581	627	335
	F2	2,312	2,171	1,980	2,018	1,302	1,093	1,063	1,228	923

Table 14: RS words_2.

Vowels	Hz	/i/	e/__i	e/__u	e/__/e,a	/a/	o/__e,a	/o/__u	/o/__i	/u/
Mean	F1	292	418	447	453	653	526	519	524	314
	F2	2,252	1,869	1,791	1,767	1,231	1,004	967	980	792
DS	F1	12	24	25	32	44	26	29	29	15
	F2	110	64	66	64	33	56	55	64	94
Min	F1	268	390	413	382	583	452	470	438	289
	F2	2,056	1,714	1,646	1,580	1,174	853	874	847	592
Max	F1	311	498	538	531	738	581	592	570	339
	F2	2,411	1,976	1,943	1,893	1,278	1,073	1,052	1,131	931

Table 15: MM words_1.

Vowels	Hz	/i/	e/__i	e/__u	e/__/e,a	/a/	o/__e,a	/o/__u	/o/__i	/u/
Mean	F1	302	420	531	528	837	539	478	541	322
	F2	2,416	2,117	1,928	1,906	1,220	850	797	832	744
DS	F1	15	22	31	30	29	45	32	53	18
	F2	56	88	79	63	80	69	57	54	90
Min	F1	284	390	423	428	768	451	427	449	297
	F2	2,347	1,826	1,823	1,763	1,111	730	711	728	628
Max	F1	337	495	576	566	890	611	539	667	360
	F2	2,542	2,302	2,100	2,036	1,380	981	924	927	936

Table 16: MM words_2.

Vowels	Hz	/i/	e/__i	e/__u	e/__/e,a	/a/	o/__e,a	/o/__u	/o/__i	/u/
Mean	F1	301	417	520	518	840	536	445	529	315
	F2	2,433	2,157	1,964	1,964	1,211	839	808	827	724
DS	F1	17	16	27	28	27	60	30	82	22
	F2	60	48	53	56	62	48	88	57	67
Min	F1	284	381	418	424	809	441	407	431	293
	F2	2,342	2,074	1,899	1,827	1,143	729	722	729	612
Max	F1	335	461	545	548	884	687	528	703	380
	F2	2,542	2,263	2,122	2,146	1,365	948	1,094	953	882

References

Allen, Blake, Douglas Pulleyblank & Ajíbóyè Ọládiípọ̀. 2013. Articulatory mapping of Yoruba vowels: An ultrasound study. *Phonology* 30(2). 183–210.

Anderson, Starwalt & Coleen Grace. 2008. *The acoustic correlates of ATR harmony in seven- and nine-vowel African languages: A phonetic inquiry into phonological structure*. Arlington, TX: University of Texas at Arlington dissertation.

Archangeli, Diana & Douglas Pulleyblank. 1994. *Grounded phonology*. Cambridge, MA: MIT Press.

Barnes, Sonia. 2019. Variable vowel metaphony in Asturian: An acoustic analysis. *Phonetica* 76(1). 31–54.

Bates, Douglas, Martin Mächler, Ben Bolker & Steve Walker. 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67(1). 1–48.

Beltzung, Jean-Marc, Cédric Patin & Nick Clements. 2015. The feature [ATR]. In Annie Rialland, Rachid Ridouane & Harry van der Hulst (eds.), *Features in phonology and phonetics*, 217–242. Berlin: Mouton De Gruyter.

Benus, Stephan & Adamantios Gafos. 2007. Articulatory characteristics of Hungarian 'transparent' vowels. *Journal of Phonetics* 35. 271–300.

Bergmann, Christopher, Amber Nota, Simona A. Sprenger & Monika S. Schmid. 2016. L2 immersion causes non-native-like L1 pronunciation in German attriters. *Journal of Phonetics* 58. 71–86.

Bermúdez-Otero, Ricardo. 2013. Amphichronic explanation and the life cycle of phonological processes. In Patrick Honeybone & Joseph C. Salmons (eds.), *The Oxford handbook of historical phonology*, 374–399. Oxford: Oxford University Press.

Bermúdez-Otero, Ricardo. 2020. The initiation and incrementation of sound change: Community-oriented momentum-sensitive learning. *Glossa: A Journal of General Linguistics* 5(1). 121.

Bermúdez-Otero, Ricardo & Graeme Trousdale. 2012. Cycles and continua: On unidirectionality and gradualness in language change. In Terttu Nevalainen & Elizabeth Closs Traugott (eds.), *The Oxford handbook of the history of English*, 691–720. Oxford: Oxford University Press.

Boersma, Paul & David Weenink. 2011. *Praat: Doing phonetics by computer* (Computer program), Version 5.2. Available at: http://www.praat.org/.

Calabrese, Andrea. 1984. Metaphony in salentino. *Rivista di Grammatica Generativa* 9–10. 3–140.

Calabrese, Andrea. 1995. A constraint-based theory of phonological markedness and simplification procedures. *Linguistic Inquiry* 2(26). 373–463.

Calabrese, Andrea. 1998. Metaphony revisited. *Rivista di Linguistica* 11. 7–69.

Calabrese, Andrea. 2001. The fronting of ū and the status of the feature ATR in Romance. In Lori Repetti (ed.), *Phonological theory and the dialects of Italy*, 59–88. Amsterdam: John Benjamins.

Calabrese, Andrea. 2005. *Markedness and economy in a derivational model of phonology*. Berlin: Mouton De Gruyter.

Calabrese, Andrea. 2009. Markedness theory vs. phonological idiosyncrasies in a realistic model of language. In Eric Raimy & Charles E. Cairns (eds.), *Contemporary views on architecture and representations in phonological theory*, 261–304. Cambridge, MA: The MIT Press.

Calabrese, Andrea. 2011. Metaphony in Romance. In Marc van Oostendorp, Colin Ewen, Elizabeth Hume & Karen Rice (eds.), *The Blackwell companion to phonology*, 2631–2661. Oxford: Wiley-Blackwell.

Calabrese, Andrea. 2016. Markedness effects in the Gallo-Romance vowel system. *Diachronique* 5. 153–196.

Calabrese, Andrea. 2019. *Essays in morpho-phonology: A theory of PF. From syntax to phonology in Sanskrit and Italian verb systems*. University of Connecticut Ms. Available at: https://andrea-calabrese.uconn.edu/publications/.

Calabrese, Andrea. 2025. High vowel fission in Southern Salentino metaphony. *Paper presented at the 55th Linguistic Symposium on Romance Languages, 2025, Pontificia Universidad Católica, Santo Domingo, Dominican Republic, 10–12 September*.

Calabrese, Andrea & Mirko Grimaldi. In press. Metaphony in Romance updated. In Kuniya Nasukawa, Bridget Samuels, Geoff Schwartz & Miklós Törkenczy (eds.), *The Blackwell companion to phonology 2*. Oxford: Wiley-Blackwell.

Cole, Jennifer & Loren Trigo. 1988. Parasitic harmony. In Harry van der Hulst & Norval Smith (eds.), *Features, segmental structure and harmony processes (Part II)*, 19–38. Berlin: Mouton De Gruyter.

Core Team. 2023. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Available at: https://www.R-project.org/.

Davidson, Lisa. 2006. Comparing tongue shapes from ultrasound imaging using smoothing spline analysis of variance. *Journal of the Acoustical Society of America* 120(1). 407–415.

Edmondson, Jerold A., Cécile M. Padayodi, Zeki Majeed Hassan & John H. Esling. 2007. The laryngeal articulator: Source and resonator. In Jürgen Trouvain & William J. Barry (eds.), *Proceedings of the 16th international congress of phonetic sciences*, 2065–2068. Saarbrücken: Saarland University.

Esling, John H., Scott R. Moisik, Allison Benner & Lise Crevier-Buchman. 2019. *Voice quality: The laryngeal articulator model*. Cambridge, UK: Cambridge University Press.

Gick, Bryan, Douglas Pulleyblank, Fiona Campbell & Ngessimo Mutaka. 2006. Low vowels and transparency in Kinande vowel harmony. *Phonology* 23. 1–20.

Gilbert, Richard J., Vitaly J. Napadow, Terry A. Gaige & Van J. Wedeen. 2007. Anatomical basis of lingual hydrostatic deformation. *Journal of Experimental Biology* 210(23). 4069–4082.

Greca, Pia, Michele Gubian & Jonathan Harrington. 2024. The relationship between the coarticulatory source and effect in sound change: Evidence from Italo-Romance metaphony in the Lausberg area. *Laboratory Phonology* 15(1). https://doi.org/10.16995/labphon.9228.

Grimaldi, Mirko. 2003. *Nuove ricerche sul vocalismo tonico del Salento meridionale*. Alessandria: dell'Orso.

Grimaldi, Mirko. 2009. Acoustic correlates of phonological microvariations. The case of unsuspected highly diversified metaphonetic processes in a small area of Southern Salento (Apulia). In Danièl Tock & W. Leo Wetzels (eds.), *Romance languages and linguistic theory 2006*, 89–109. Amsterdam/Philadelphia: John Benjamins.

Grimaldi, Mirko & Andrea Calabrese. 2018. Metaphony in Southern Salento: New analysis and new data. In Roberta D'Alessandro & Diego Pescarini (eds.), *Advances in Italian dialectology*, 253–291. Leiden: Brill.

Grimaldi, Mirko, Andrea Calabrese, Sigona Francesco, Garrapa Luigina & Bianca Sisinni. 2010. Articulatory grounding of Southern Salentino harmony processes. In *11th annual conference of the International Speech Communication Association (ISCA), interspeech, 1561–1564. Makuhari, Japan, 26–30 September*. New York: Curran.

Grimaldi, Mirko, Sandra Miglietta, Francesco Sigona & Andrea Calabrese. 2016. On integrating different methodologies in phonological research: Acoustic, articulatory, behavioral and neurophysiological evidence in the study of a metaphonic system. In Francesc Torres-Tamarit, Kathrin Linke & Marc van Oostendorp (eds.), *Approaches to metaphony in the languages of Italy*, 195–219. Berlin: Mouton De Gruyter.

Gu, Chong. 2002. *Smoothing spline ANOVA models*. New York: Springer.

Guión, Susan G., Mark W. Post & Doris L. Payne. 2004. Phonetic correlates of tongue root vowel contrasts in Maa. *Journal of Phonetics* 32. 517–542.

Halle, Morris & Kenneth Stevens. 1969. On the feature advanced tongue root. *Quarterly Progress Report (MIT Research Laboratory of Electronics)* 94. 209–215.

Hillenbrand, James, Laura A. Getty, Michael J. Clark & Kimberlee Wheeler. 1995. Acoustic characteristics of American English vowels. *Journal of the Acoustical Society of America* 97(5). 3099–3111.

Hothorn, Torsten, Frank Bretz & Peter Westfall. 2008. Simultaneous inference in general parametric models. *Biometrical Journal* 50(3). 346–363.

Hudu, Fusheini. 2010. *Dagbani tongue-root harmony: A formal account with ultrasound investigation*. British Columbia, Canada: University of British Columbia dissertation.

Hudu, Fusheini, Amanda Miller & Douglas Pulleyblank. 2009. Ultrasound imaging and theories of tongue root phenomena in African languages. In Peter K. Austin, Oliver Bond, Monik Charette, David Nathan & Peter Sells (eds.), *Proceedings of conference on language documentation and linguistic theory*, vol. 2, 153–163. London: SOAS.

Jessen, Michael. 1998. *Phonetics and phonology of tense and lax obstruents in German*. Amsterdam, Philadelphia: Benjamins.

Kier, William. M. & Kathleen K. Smith. 1985. Tongues, tentacles, and trunks: The biomechanics of movement in muscular hydrostats. *Zoological Journal of the Linnean Society* 83(4). 307–324.

Kiparsky, Paul. 2006. The amphichronic program vs evolutionary phonology. *Theoretical Linguistics* 32. 217–236.

Kirkham, Sam & Claire Nance. 2017. An acoustic-articulatory study of bilingual vowel production: Advanced tongue root vowels in Twi and tense/lax vowels in Ghanaian English. *Journal of Phonetics* 62. 65–81.

Labov, William. 2001. *Principles of linguistic change*, vol. 2: Social factors. Oxford: Blackwell.
Labov, William. 2010. *Principles of linguistic change*, vol. 3: Cognitive and cultural factors. Oxford: Blackwell.
Labov, William. 2014a. The sociophonetic orientation of the language learner. In Chiara Celata & Silvia Calamai (eds.), *Advances in sociophonetics (Studies in Language Variation 15)*, 17–29. Amsterdam: John Benjamins.
Labov, William. 2014b. What is to be learned: The community as the focus of social cognition. In Martin Pütz, Justyna A. Robinson & Monika Reif (eds.), *Cognitive sociolinguistics: Social and cultural variation in cognition and language use*, 23–51. Amsterdam: John Benjamins.
Ladefoged, Peter. 1968. *A phonetic study of West African languages*. Cambridge, UK: Cambridge University Press.
Ladefoged, Peter & Ian Maddieson. 1996. *The sounds of the world's languages*. Oxford: Wiley-Blackwell.
Lausberg, Heinrich. 1939. *Die Mundarten Südlukaniens*. Berlin: Mouton De Gruyter.
Laver, John. 1994. *Principles of phonetics*. Cambridge, UK: Cambridge University Press.
Lindau, Mona. 1975. Features for vowels. *UCLA Working Papers in Phonetics* 30. 16–21.
Lindau, Mona. 1978. Vowel features. *Language* 54(3). 541–563.
Lindau, Mona. 1979. The feature expanded. *Journal of Phonetics* 7. 163–177.
Lindau, Mona, Leon Jacobson & Peter Ladefoged. 1972. The feature advanced tongue root. *UCLA Working Papers in Phonetics* 22. 76–94.
Lindau-Webb, Mona. 1987. Acoustic correlates of TENSE-LAX vowels and ATR vowels. *The Journal of the Acoustical Society of America* 82. S116.
Loporcaro, Michele. 2016. Metaphony and diphthongization in Southern Italy: Reconstructive implications for sound change in early Romance. In Francesc Torres-Tamarit, Kathrin Linke & Marc van Oostendorp (eds.), *Approaches to metaphony in the languages of Italy*, 55–8719. Berlin: Mouton De Gruyter.
Maddieson, Ian. 2003. The sounds of the Bantu languages. In Mark Van de Velde, Koen Bostoen, Derek Nurse & Gérard Philippson (eds.), *The Bantu languages*, 15–41. London, New York: Routledge.
Maiden, Martin. 1991. *Interactive morphophonology. Metaphony in Italy*. London, New York: Routledge.
Mancarella, Giovan Battista. 1978. Origine e diffusione della metafonia nel Salento. In Alberto Varvaro (ed.), *Atti del XIV Congresso Internazionale di Linguistica e Filologia Romanza*, 117–124. Amsterdam: John Benjamin.
Mancarella, Giovan Battista. 1998. *Salento. Monografia regionale della "Carta dei Dialetti Italiani"*. Lecce: Edizioni del Grifo.
McCloy, Daniel. 2015. *phonR: Tools for phoneticians and phonologists*. R package version 1.0-1. Available at: https://rdrr.io/cran/phonR/.
Melillo, Michele. 1986. *Prosodia e vocalismo tonico dei dialetti di Puglia nelle versioni della parabola del figliol prodigo*, vol. VII. Università degli Studi di Bari: Cattedra di Dialettologia Italiana della Facoltà di Lettere.
Menéndez Pidal, Ramón. 1952. *El dialecto leonés*. Oviedo: Instituto de Estudios Asturianos.
Miglietta, Sandra. 2013. *Allophonic and phonemic perception: A combined acoustic, behavioral and electrophysiological study*. Torino: Editore dell'Orso.
Miglietta, Sandra, Mirko Grimaldi & Andrea Calabrese. 2013. Conditioned allophony in speech perception: An ERP study. *Brain & Language* 126(3). 285–290.
Moisik, Scott R., Ewa Czaykowska-Higgins & John H. Esling. 2021. Phonological potentials and the lower vocal tract. *Journal of the International Phonetic Association* 51. 1–35.
Nevins, Andrew. 2010. *Locality in vowel harmony*. Cambridge, MA: MIT Press.

Painter, Colin. 1973. Cineradiographic data on the feature 'Covered' in Twi vowel harmony. *Phonetica* 28. 97–120.
Parlangeli, Oronzo. 1953. Sui dialetti Romanzi e Romaici del Salento. *Memorie dell'Istituto Lombardo di Scienze e Lettere, classe di Lettere, Scienze Morali e Storiche* 15–16(III). 93–198.
Peterson, Gordon & Harold L. Barney. 1952. Control methods used in a study of the vowels. *Journal of the Acoustical Society of America* 24(2). 175–184.
Rodríguez Castellano, Lorenzo. 1952. *La variedad dialectal del Alto Aller*. Oviedo: Instituto de Estudios Asturianos.
Rohlfs, Gerhard. 1966. *Grammatica storica della lingua italiana e dei suoi dialetti*, vol. I, Fonetica. Torino: Einaudi.
Savoia, Leonardo M. 2015. *I dialetti italiani. Sistemi e processi fonologici nelle varietà di area italiana e romancia*. Pisa: Pacini.
Scobbie, James. 2005. The phonetics phonology overlap. *QMU Speech Science Research Centre Working Papers* WP-13. 1–30.
Stehl, Thomas. 1988. Puglia und Salento. In Gunther Holtus, Michael Metzeltin & Christian Schmitt (eds.), *Lexikon der Romanistischen Linguistik*, vol. IV, 695–716. Tübingen: Max Niemeyer Verlag.
Steriade, Donca. 1981. *Parameters of metrical vowel harmony rules*. Massachusetts Institute of Technology Ms.
Stevens, Kenneth N. 2000. *Acoustic phonetics*. Cambridge, MA: The MIT Press.
Stewart, John M. 1967. Tongue root position in Akan vowel harmony. *Phonetica* 16. 185–204.
Tabain, Marija, Jaye Padgett, Gertrud Schneider-Blum, Adele Gregory & Richard Beare. 2024. An acoustic study of ATR in Tima vowels: Vowel quality, voice quality and duration. *Phonology* 41. e2.
Tiede, Mark K. 1996. An MRI-based study of pharyngeal volume contrasts in Akan and English. *Journal of Phonetics* 24. 399–421.
Yang, Byunggon. 1996. A comparative study of American English and Korean vowels produced by male and female speakers. *Journal of Phonetics* 24. 245–261.