Metaphony in the Tricase Southern Salentino Variety: Acoustic, Articulatory and Phonological Analysis

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Abstract 150-250 Words

Southern Salentino varieties have a five-vowel system, /i, ɛ, a, ɔ, u/, displaying harmonic alternations in stressed mid-vowels: /ɛ/, /ɔ/ raise to the mid-close [e], [o] when followed by the high vowels [i], [u], respectively. This harmony process is traditionally referred to as metaphony. Southern Salentino metaphony is characterized by microvariation. We investigated the Southern Salentino variety spoken in Tricase, focusing our analysis both on the inter-speaker and intra-speaker variation. Our first objective is to explain the acoustic and articulatory nature of the metaphonic patterns and to establish what features are involved in the assimilatory process. Acoustically, we show that the metaphonic variant [e] has lower F1 and higher F2 values than /ɛ/, while the metaphonic variant [o] has lower F1 and lower F2 values than /ɔ/. We also demonstrate that the articulatory feature [±ATR] is significantly correlated with the metaphonic contrasts. Our second objective is to develop an appropriate phonological analysis of the phenomenon and describe the interacting parameters that may generate the microvariation, we suggest that an important factor in the variation is the presence of a constraint against [+back, +ATR] vowels preventing high [+back, +ATR] triggers and/or mid [+back, +ATR] outcomes. We also suggest that, although phonologized, the metaphonic process has not yet become normative in the language of the community thus leading to inter-speaker and intra-speaker variation.

Keywords: 4-6
Metaphony, harmony, microvariation, phonologization, acoustic-articulatory analysis, phonological analysis

1. Introduction

1.1 Southern Salentino metaphony

The Italo-Romance Southern Salentino varieties are characterized by a five-vowel system as shown in (1)[1]:

(1) i   u
        ɛ   ɔ
           a

This system displays a harmonic process raising stressed mid-vowels /ɛ/, /ɔ/ to the mid-close [e], [o] when followed by high vowels [i], [u]. This process occurs both when the target vowels are in open and closed syllables (Grimaldi 2003, 2009). In Romance linguistics, this kind of harmonic change is traditionally called *metaphony*; we will adopt this term here[2]. While Southern Salentino metaphony displays intrinsic microvariation, the data of the Lucugnano variety in (2) illustrate the most general application of the process (cf. Figure 1): /ɛ, ɔ /→[e, o]/__[i, u]. The microvariation process will be discussed in the next Section.

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

To better understand this process, we focus on Tricasino, the variety of Southern Salentino spoken in Tricase (cf. Figure 1). Our first objective is to investigate the acoustic and articulatory nature of the metaphonic patterns and to establish what features are involved in the assimilatory process. We then aim to study what interacting parameters and restrictions control the spreading of the feature/s generating the microvariation, and to develop an appropriate phonological analysis. As far as we know, acoustic-articulatory investigations for Romance varieties showing metaphony are absent. Moreover, to the best of our knowledge, very few studies have investigated harmony processes fruitfully integrating phonetic and phonological perspectives (cf. Benus and Gafos 2006; Gick *et al.* 2006).

Our findings are as follow. Tricasino metaphonic patterns acoustically involve F1 variation with some effect on F2. On the articulatory side, Tricasino patterns are correlated primarily 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 inter-speaker 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

[1] Southern Salento is found in the Province of Lecce in the Apulia region of Italy. Varieties which are subject to the metaphony under discussion are broadly located in the triangle delimited by S.M. of Leuca at South, Gallipoli at West, ad Otranto at East: cf. Figure 1.

[2] Cf. Calabrese (2011), Savoia (2015) for a relevant discussion of metaphony in other Italian and Romance varieties. See Section 4.2 for a brief discussion of the relation between the Southern Salentino patterns and those characterizing other Italo-Romance varieties.

highlighted by our acoustic and articulatory findings, but also attempt to make sense of the microvariations that characterize the same patterns in Tricasino and across all other Southern Salentino varieties.

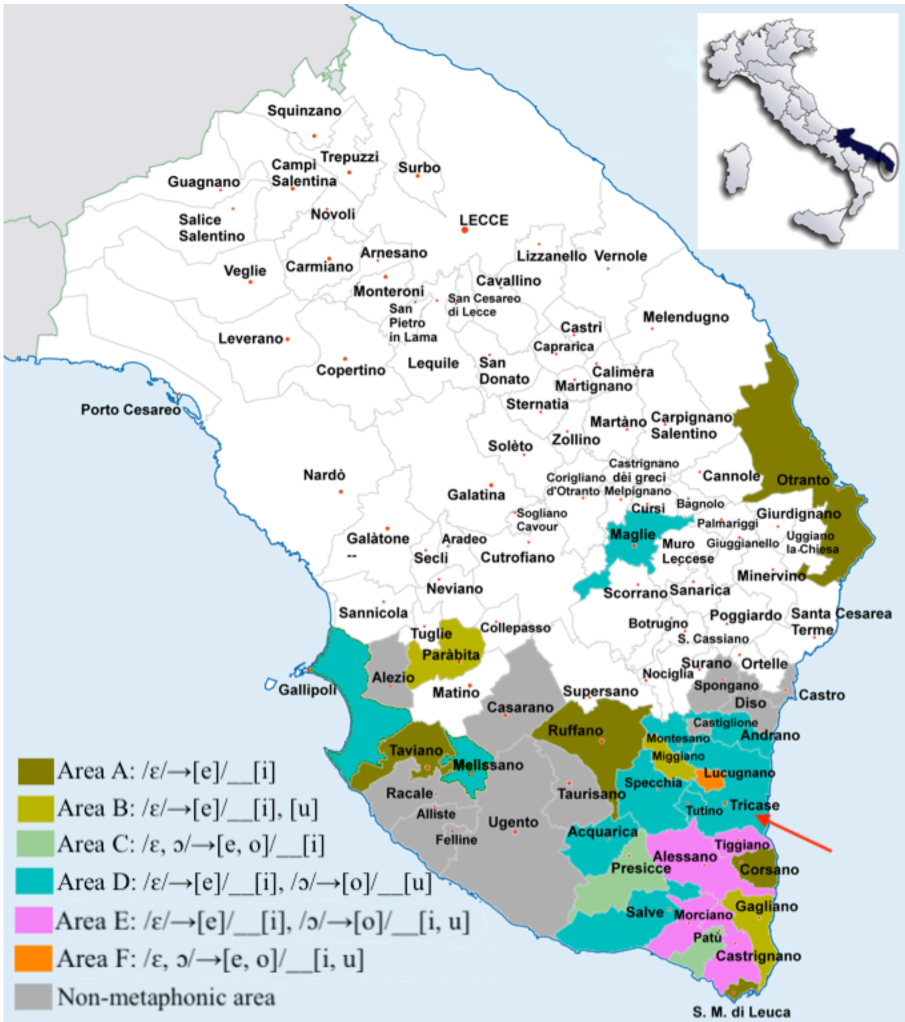

Figure 1: The province of Lecce and the Southern Salento metaphonic areas (colored); The non-metaphonic area is highlighted in gray. The white area represents the localities not yet investigated.

1.2 Metaphonic microvariations across Southern Salentino varieties

Grimaldi (2003, 2009) studied the vocalic productions in 36 localities in Southern Salentino by interviewing one speaker for each variety[3]. His acoustic investigation revealed that metaphony in Southern Salentino is affected by microvariation (cf. Figure 1)[4]. This microvariation was further supported by our finer acoustic and statistical analyses of the Tricasino variety (see Grimaldi & Calabrese

[3] For each variety, 1 male speaker aged between 50-80 (with low education background) was analyzed. The data were elicited using a questionnaire of about 600 stimuli. These stimuli included representative samples of the Salentino stressed vowels either in open or in closed syllable in all classes of words (nouns, verbs, adjectives, etc.). In order to obtain as natural data as possible, semi-structured interviews were utilized.

[4] The presence of varying metaphonic patterns in Southern Salentino varieties was first interpreted by Grimaldi (2003, 2009) as entailing across-variety grammatical dialectal microvariation of the same type as that characterizing the syntax and the morpho-syntax of Italo-Romance varieties (cf. Manzini and Savoia 2011). However, the findings from Tricasino discussed below lead to a different interpretation of this microvariation (cf. Section 6)

2018). The most common metaphonic pattern is the raising of /ɛ/→[e] before [i]; alternative applications of the assimilatory process are also found: i.e., in the case of /ɛ/→[e] before [u], /ɔ/→[o] before [i], and /ɔ/→[o] before [u][5].

Statistical analysis allows us to better interpret this kind of metaphonic microvariation by considering the levels of significance of each assimilatory pattern. For instance, if we choose a range of statistical significance from 0.0001 to 0.05, we can obtain solid information about the different impacts with which unstressed vowels [i] and [u] affect the stressed vowels /ɛ/ and /ɔ/. According to statistical notation, from 0.0001 to 0.001 represents EXTREMELY SIGNIFICANT LEVELS, from 0.001 to 0.01 VERY SIGNIFICANT LEVELS, and from 0.01 to 0.05 a SIGNIFICANT LEVELS (cf. Eddington 2015)[6]. This analysis is represented in Figure 2, where the level of significance is given for each locality investigated (on the vertical axis) and each assimilatory pattern (on the horizontal axis) of each assimilatory pattern is given. What emerges is that the pattern /ɛ/→[e]/__[i] occurs in all investigated varieties, with some only exhibiting this pattern. The second most common pattern is /ɔ/→[o]/__[u]. These two patterns are generally characterized by extremely or very significant levels of statistical significance, and many varieties display only /ɛ/→[e]/__[i] and /ɔ/→[o]/__[u]. In addition, in some varieties we can find /ɛ/→[e]/__[u] (with a significant level), and/or /ɔ/→[o]/__[i] (with a very significant level).

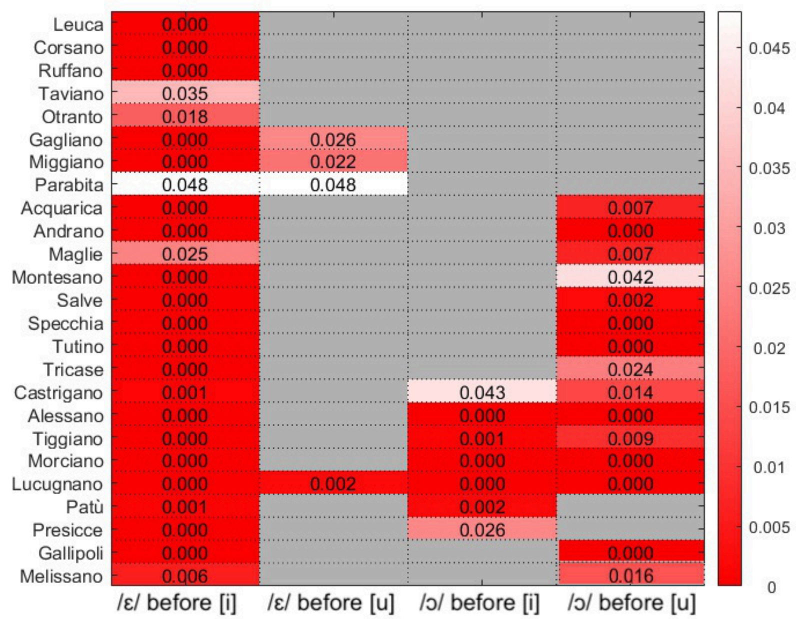

Figure 2: Different metaphonic action of unstressed [i] and [u] on the preceding stressed /ɛ/ and /ɔ/ vowels for each speaker recorded in the 36 localities of Southern Salento investigated by Grimaldi (2003). On the vertical: the localities. On the horizontal: the metaphonic contexts whether metaphonic raising occurs in the environments listed. The levels of statistical significance are represented in each column with different shades from red (extremely significant level) to white (significant level). Gray = not significant.

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[5] We focus here on Southern Salentino varieties that do not display any other type of metaphonic patterning such as diphthongization (e.g., /ɛ/→[je] before [i] and/or /ɔ/→ before [we]) which are found in central and northern Salentino varieties (see Section 6.1 for a brief discussion). This is because these alternative patterns could be a confounding factor in the establishment of the analysis.

[6] The theory behind a statistical test of significance essentially involves setting a null Hypothesis and a competing alternative hypothesis. The null hypothesis (H0) is generally the negation of the research hypothesis (H1): in our case, the hypothesis is that there is a difference between the realization of /ɛ/ and /ɔ/ followed by [ɛ], [a] and the same vowels followed by [i], [u]. While drawing an inference in testing the hypothesis, we need to choose the level of significance (the probability of a Type I error rejecting the null hypothesis when it is true) and the estimated p-value for the given data set of the study. The p-value indicates how probable the results are due to chance. So, p=0.05 means that there is a 5% probability that the results are due to random chance, p=0.001 means that the chances are only 1 in a thousand, and so on.

Thus, final [i] and [u] show a clear asymmetry with respect to their role as metaphony triggers: [i] is always a trigger of the metaphonic process; [u] is often not a trigger and never the only trigger. Systems in which 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 clear asymmetry with respect to their role as metaphony targets: /ɛ/ is the preferred target of Southern Salentino metaphony and often is the only target of the phenomenon; /ɔ/ is never the only target. Therefore, some variety can display the patterns /ɛ/→[e]/__[i] or /ɛ/→[e]/__[i, u] but there is no variety that display just the patterns /ɔ/→[o]/__[i], or /ɔ/→[o]/__[i, u]. These data suggest that back vowels may have a special status: that is, unstressed [u] is preferably not a metaphony trigger and stressed /ɔ/ is preferably not a metaphony target. As already mentioned, the only exception is the metaphonic pattern /ɔ/→[o]/__[u], which together with /ɛ/→[e]/__[i], is also characterized by a very significant statistical level.

1.3 The present study

Following Grimaldi et al. (2010), an in-depth investigation of the Tricase variety was carried out by Miglietta (2013), who conducted a preliminary acoustic analysis and acquired articulatory data (10 subjects in total). In that research, behavioral and electrophysiological measurements were also collected to investigate the perception and processing of the allophones with respect to their corresponding phonemes (cf. Miglietta 2013; Miglietta, Grimaldi & Calabrese 2013 and Section 6.2 for a discussion of these data). The findings of Miglietta (2013) revealed a striking inter-speaker microvariation, showing that the same metaphonic patterns found by Grimaldi (2003) across speakers of Southern Salentino varieties are also found across speakers of Tricasino (remember that Grimaldi 2003 analyzed only one speaker for each of the investigated localities).

In this work, we improve the preliminary acoustic analysis conducted by Miglietta (2013) by adopting a more appropriate statistical method. We also investigate the articulatory data not analyzed in that work, picking the best articulatory recordings to ensure solid data for the statistical analysis: thus, six speakers were considered for the articulatory analysis (Experiment 1). The microvariation observed in different conditions baffled us leading us to hypothesize that the variability may also characterize the productions of single speakers. Thus, in the Experiment 2, we investigate intra-speaker microvariation: i.e., three Tricase speakers were asked to produce a set of words and pseudo-words. After an hour, they were again asked to produce the same set. In this case, only an acoustic analysis was performed. The same patterns of microvariation seen in Experiment 1 are evidenced again here.

2. Experiment 1: inter-speakers microvariation

2.1 Methods

2.1.1 Subjects, data acquisition, and analysis

Six speakers (2 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 of 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 both in open and closed syllables. The selected words specifically included contexts in which the metaphonic raising may occur (+met) or may not (-met), as exemplified in (3):

(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 low vowel /a/ were also recorded separately. The list of stimuli is reported in *Appendix 1*.

The subjects were seated in a soundproof room and were asked to read word stimili at a normal rate. These stimuli were embedded in a carrier phrase *Ieu ticu ___moi* 'I say ___now' which appeared on a computer screen. 10 stimuli for each of the five target vowels were used: they were 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 considered together as they do not trigger metaphonic assimilation), and so on for /ɔ/. Where possible, we used words in which /ɛ/ and /ɔ/ were surrounded by labial and labiodental consonants that have a small effect of the tongue body and root position. So, 90 stimuli for each subject, for a total amount of 540 stimuli, randomly interchanged, were used for elicitation.

The stimuli were recorded with a Shure SM58_LCE microphone, using the CSL 4500 recording system at a sampling rate of 22.05 kHz at 16-bit precision. The entire speaker productions were segmented and normalized in peak amplitude by means of Praat 5.2 (Boersma and Weenink 2011). For each vowel, total duration as well as F0, F1, F2 and F3 were measured; however, for the aim of this work, only F1 and F2 were taken into consideration for further analysis because these formants are considered the main acoustic features involved in harmony processes (see Sections 2.1.2, 4.2.1). The formant values were measured in the vowel steady tract (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 synchronously acquired together with the audio signal by means of an external a/v analog-to-digital acquisition card, and then recorded in real-time on a dedicated PC (cf. Grimaldi *et al.* 2016). The ultrasound probe was rigidly locked into a fixed position on a microphone stand appropriately adapted. To avoid the transducer pressure on the soft tissue of the jaw, an acoustic standoff eliminating upward pressure of the tissue was used. The two sides of the head of the subject were stabilized with an adjustable wood system built at CRIL. This system allows the speaker to rest their forehead steadily so that the whole tongue contour—from the tip to the shadow of the hyoid bone—can be captured and analyzed. The UltraSound (US) a/v stream has been segmented offline by an automatic software procedure developed at CRIL, on the basis of audio pulses superimposed to the speech signal before and after each sentence during recording (Grimaldi *et al.* 2016). For each segmented sentence, looking at the acoustic waveform, the operator manually placed labels around the time intervals where the relevant vowels occurred, so that the corresponding ultrasound pictures could be identified.

The analysis on the US data were 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 tongue surface. This was done semi-automatically using the *Articulate Assistant Advanced* (AAA) software by Articulate Instruments Ltd.

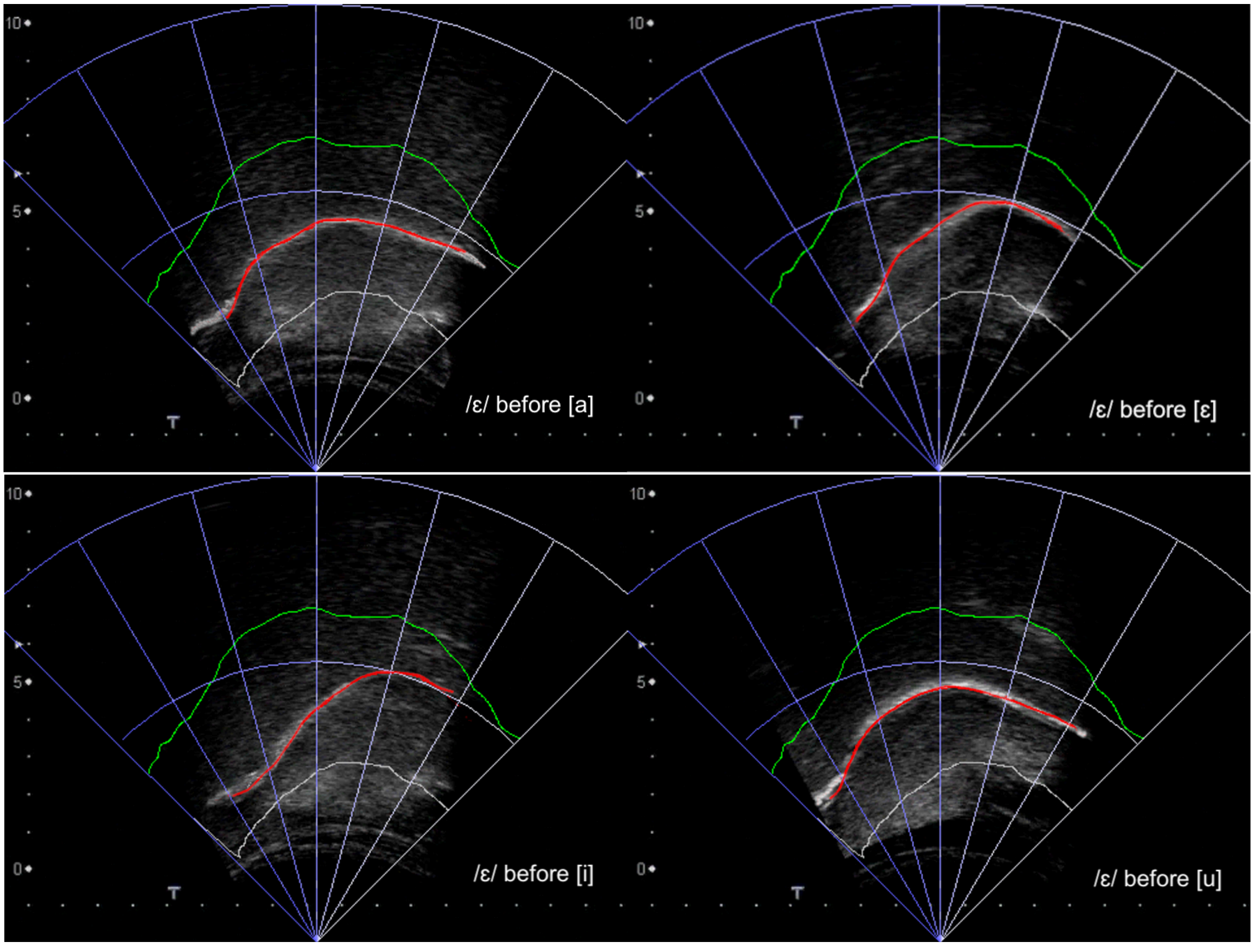

Figure 3: Examples of ultrasound images of /ɛ/ before [a], [ɛ], [i], and [u] produced by the speaker LG (cf. Section 3.1.2) with the tongue contour highlighted by the red line. In the vertical axis the tongue height is represented in centimeters.

Firstly, the area inside which the software looks for the brightest lower edge was specified. Once the AAA finds such an edge, a contour is fitted to it. This fitting is, however, not perfect. All the frames have to be inspected and the fitted contours manually corrected. The red curve on the image represents the tongue surface contour, and the green and grey curves specify the boundaries inside which AAA looks for the lower brighter edge and fits the tongue contour. Examples of fitted tongue contours are given in Figure 3 and 4.

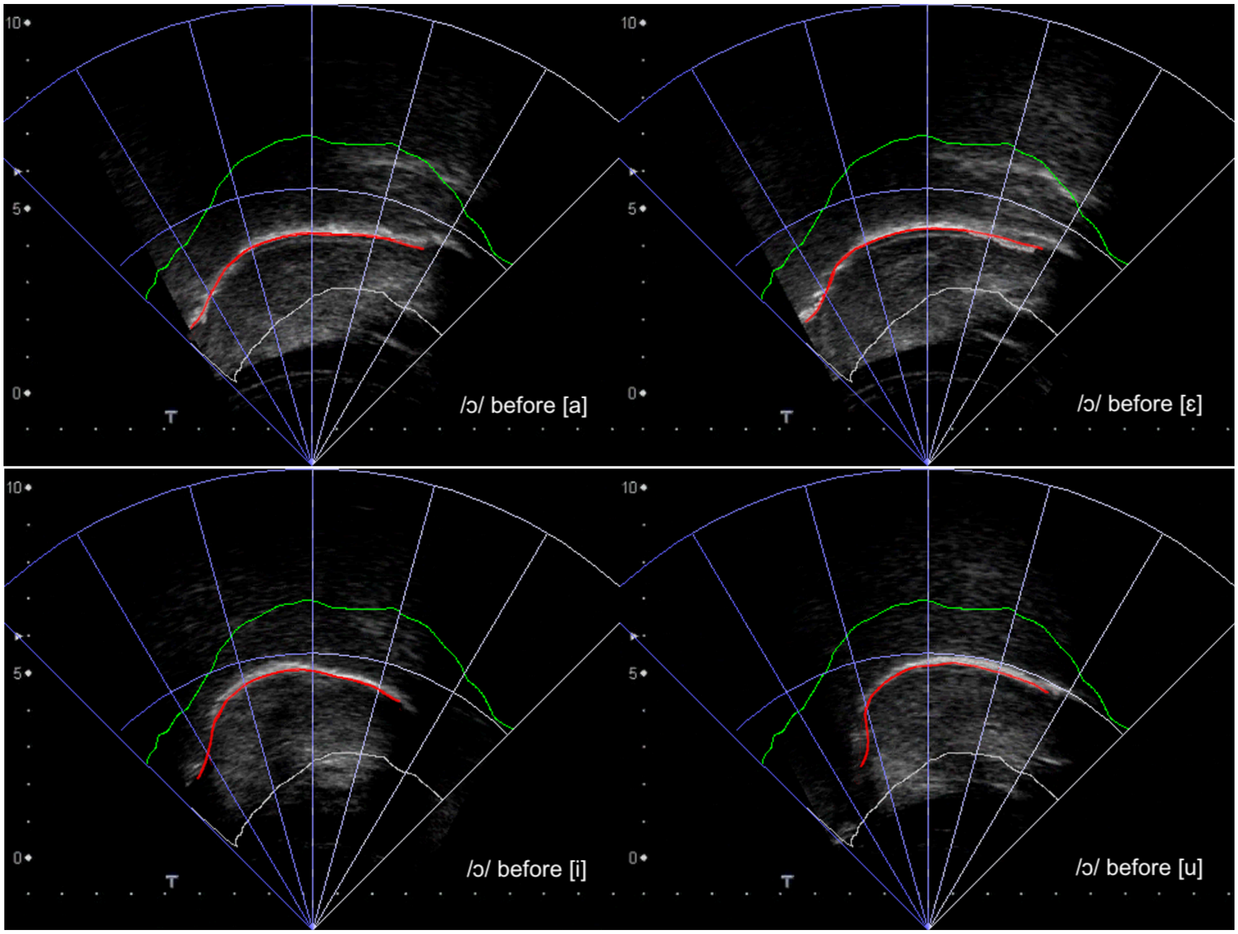

Figure 4: Examples of ultrasound images of /ɔ/ before [a], [ɛ], [i], and [u] produced by the speaker LG (cf. Section 3.1.2) with the tongue contour highlighted by the red line. In the vertical axis the tongue height is represented in centimeters.

2.1.2 Statistical analysis

For the acoustic analysis, an independent t-test was carried out to examine the assimilatory effects found in the metaphonic contexts: i.e., mid-vowels /ɛ/ and /ɔ/ before [i], [u] in comparison to the non-metaphonic contexts /ɛ/ and /ɔ/ before [ɛ], [a]. Also, triggers [i], [u] were statistically compared to determine whether they impact the metaphonic outputs of the targets /ɛ/, /ɔ/ differently. This was done both for F1 and F2. Due to the statistical protocol design, samples of one vocalic context are considered independent of any other sample of the opposite context. So, we compared the F1 and F2 Hz values of the vowels illustrated in (4):

(4) a. /ɛ/ before [i] ~ /ɛ/ before [ɛ], [a]
/ɛ/ before [u] ~ /ɛ/ before [ɛ], [a]
/ɛ/ before [u] ~ /ɛ/ before [i]

b. /ɔ/ before [i] ~ /ɔ/ before [ɛ], [a]
/ɔ/ before [u] ~ /ɔ/ before [ɛ], [a]
/ɔ/ before [u] ~ /ɔ/ before [i]

In order to understand what articulatory feature is involved in the Tricase metaphony, we used the Smoothing Spline ANOVA approach to compare tongue curves (Gu 2002; Davidson 2006). The Smoothing Spline ANOVA is based on an inferential statistic method, used to study similarities and differences in the shape of two groups of curves. It is applied to studies in medical science, environmental science, and epidemiology, and may be applied to compare groups of tongue curves produced by the same subject. In our case, for each subject, the tongue curves recorded by 10 repetitions of /ɛ/ before [i] and [u] are compared with the tongue curves recorded by 10 repetitions of /ɛ/ before [ɛ]/[a] and with the tongue curves obtained by 10 repetitions of the metaphonic triggers [i] and [u]. The same comparison was conducted with /ɔ/ (cf. Section 3.1.2).

This statistical method has the advantage to determine whether or not there are significant differences between the tongue curves belonging to two groups as well as which sections—i.e., root, body, or blade of the tongue curves—are different (Davidson, 2006). When multiple repetitions of an utterance are collected, smoothing splines in conjunction with Bayesian confidence intervals are an appropriate method to account for the shapes that best fit the data and the variance in production (Davidson 2006). Given two groups of tongue curves, the corresponding Smoothing Splines are computed: they are particular curves that provide the best fit to all the data points belonging to each group (cf. Figure 5).

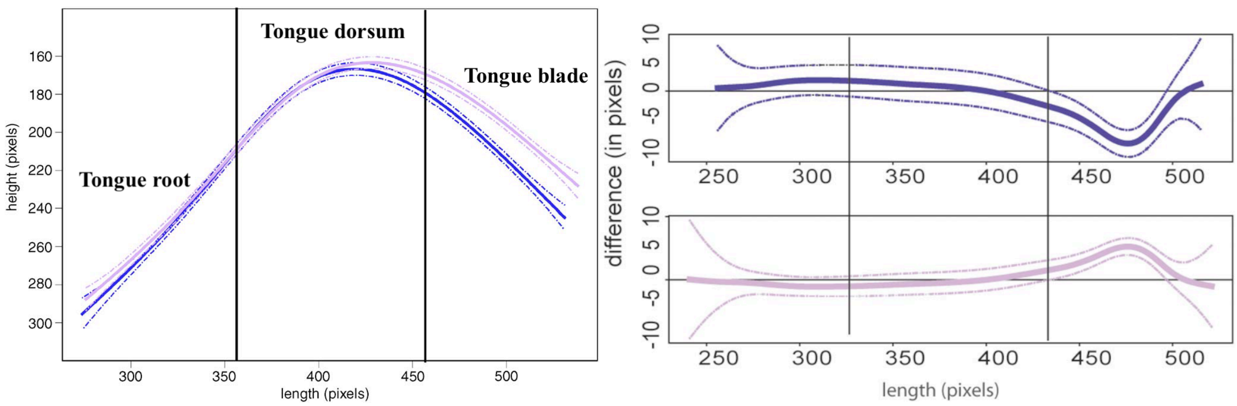

Figure 5: on the left: smoothing spline estimate and 95% Bayesian confidence interval for comparison of the mean curves for /g/ in "bag dazzled" (dark blue line) and "Baghdad" (pink line) produced by an American English native male speaker. On the right: interaction effects with Bayesian confidence intervals for the shapes for /g/ in "bag dazzled" and "Baghdad". The splines representing the interaction effect are mirror images because they represent the difference of main effect spline from the spline that best fits all data for "bag dazzled" and "Baghdad." Both images are shown because the confidence intervals can be different. The *x axis* is length, and the *y axis* is the difference between each data set and the spline that fits 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 demarcate the part of the interaction curve that is not significantly different. Adapted from Davidson (2006).

The Smoothing Spline for each data set is termed the *main group effect*, and is constructed around each the 95% Bayesian confidence interval. The comparison of the two groups of tongue curves is performed with the *interaction diagram*, which represents a plot of the difference between the Smoothing Spline for each data set and the Smoothing Spline that is the best fit to all of the data. So, the 95% Bayesian confidence interval is constructed once more, and the difference between the splines is significant when the confidence interval does not encompass the zero on the *y* axis (cf. Figure 5). The Smoothing Spline ANOVA analysis has been done by means of a Matlab tool developed at CRIL and the R package "gss" (Gu 2002).

2.2 Results

2.2.1 Acoustic results

For each Tricase speaker, the mean F1/F2 values in Hz of the five stressed vowels, differentiated according to the unstressed vowel context, are given in Tables 1-6 in *Appendix 2*. The results of the independent t-tests are given in Tables 7-12 also in *Appendix 2*, where the asterisks indicate the levels of statistical significance found in comparing the F1/F2 Hz values of pairs of vowels potentially affected by metaphony. The significant metaphonic effects between the six speakers are summarized in Figure 6: different shades of red highlight the levels of statistical significance reached by each metaphonic pattern. The significant metaphonic effects are represented by associating each Tricase speaker on the vertical with the potential metaphonic patterns on the horizontal.

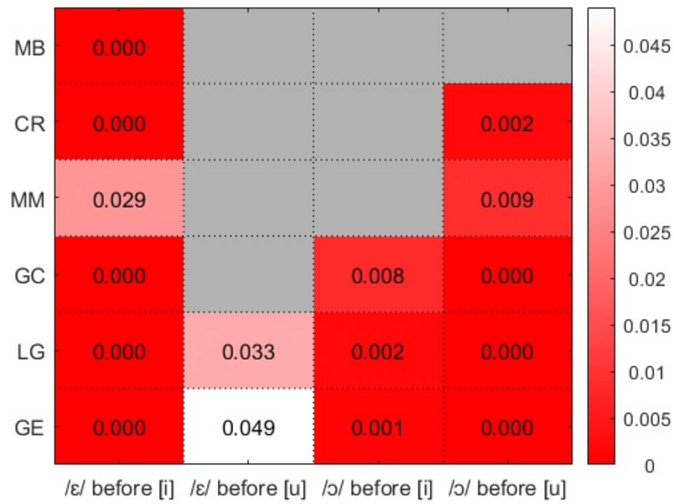

Figure 6: Different metaphonic action of unstressed [i] and [u] on the preceding stressed /ɛ/ and /ɔ/ vowels for the six Tricase speakers. On the vertical: the speakers. On the horizontal: the metaphonic contexts /ɛ/ before [i], /ɛ/ before [u], /ɔ/ before [i], and /ɔ/ before [u]. The levels of statistical significance are represented in each column with different shades from red (extremely significant level) to white (significant level). Gray = not significant.

In Figure 7, the /i/, /a/, /u/ vowels, together 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 by using ellipses on data (Figure 7 was realized by using the R statistical package McCloy (2015).

3.1.2 Articulatory results

For each speaker, the articulatory gesture which is related to a specific metaphonic pattern is represented in Figures 8-12. 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]). Tongue blade is observable up on the right, tongue body is up at the center and tongue root is down on the left of the tongue contours. Below each tongue contour, the interaction diagrams are represented both for the mid-vowel affected and the control case not affected by metaphony (cf. Section 2.1.2). Note that the different curves in Figures 8-13 involve statistical effects derived from actual tongue contours obtained through ultrasound images (as described in Sections 2.1.1 and 2.1.2). Thus, pinpoint changes in curve shapes (in the order of millimeters) are the result of different anatomical tongue articulations that generate significant acoustic effects: i.e., the allophonic variants due to metaphonic action.

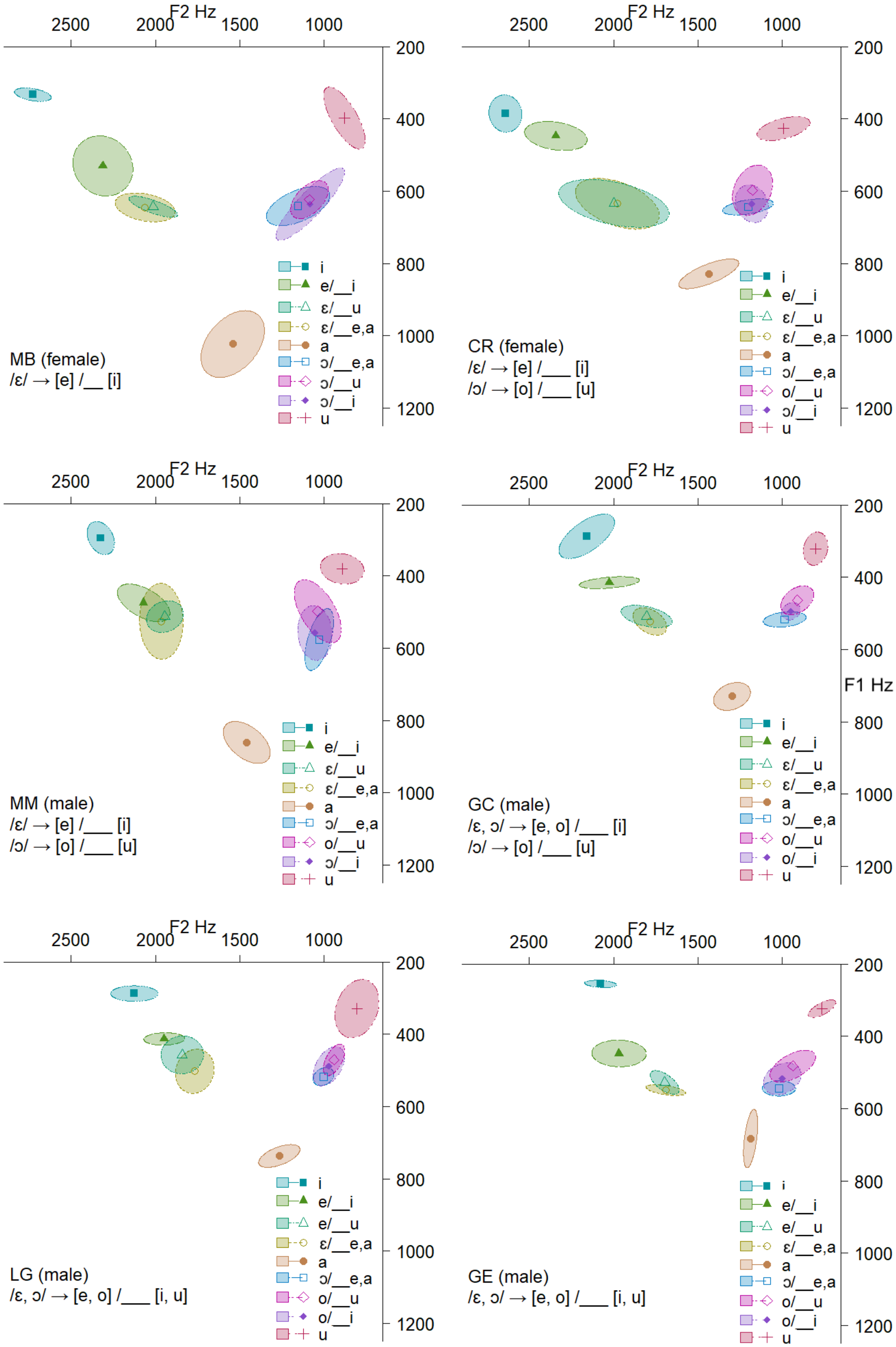

Figure 7: Scatter plots based on F1 and F2 Hz values of the six Tricase speakers investigated. Mandarin vowels. Significant metaphonic adjustments affecting the mid-vowels /ɛ/, /ɔ/ are shown. Different colors and symbols represent different vowel categories. Each ellipse encompasses 68,8% of data points for one vowel category.

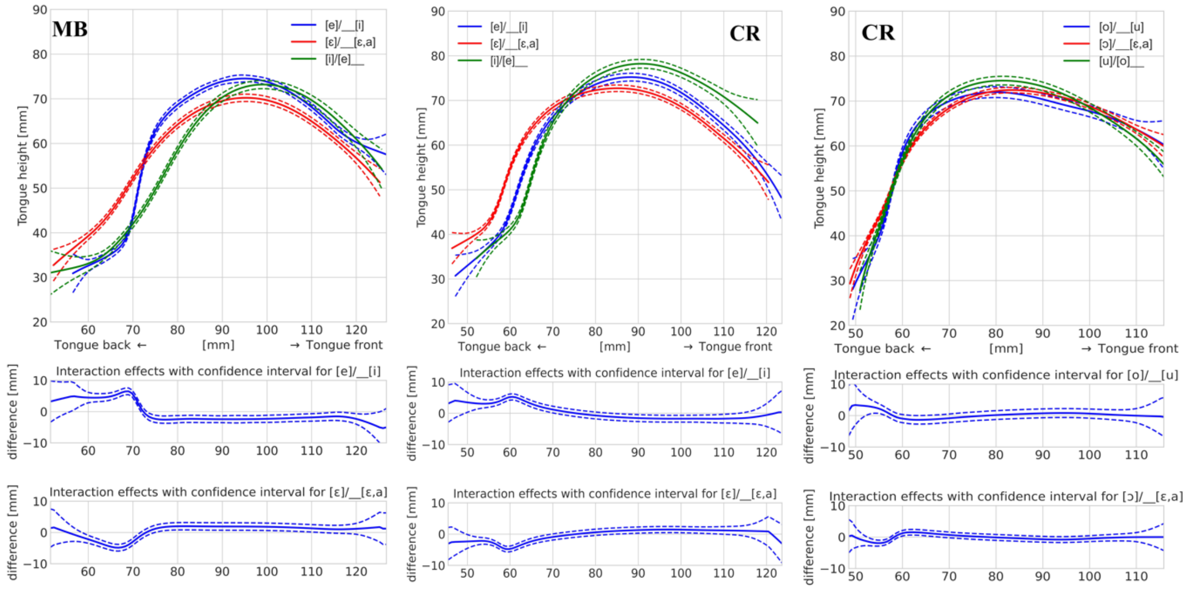

Figure 8: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in the subjects MB: /ε/→[e]/__[i] (on the left), and CR: /ε/→[e]/__[i] (on the center), /ɔ/→[o]/__[u] (on the right).

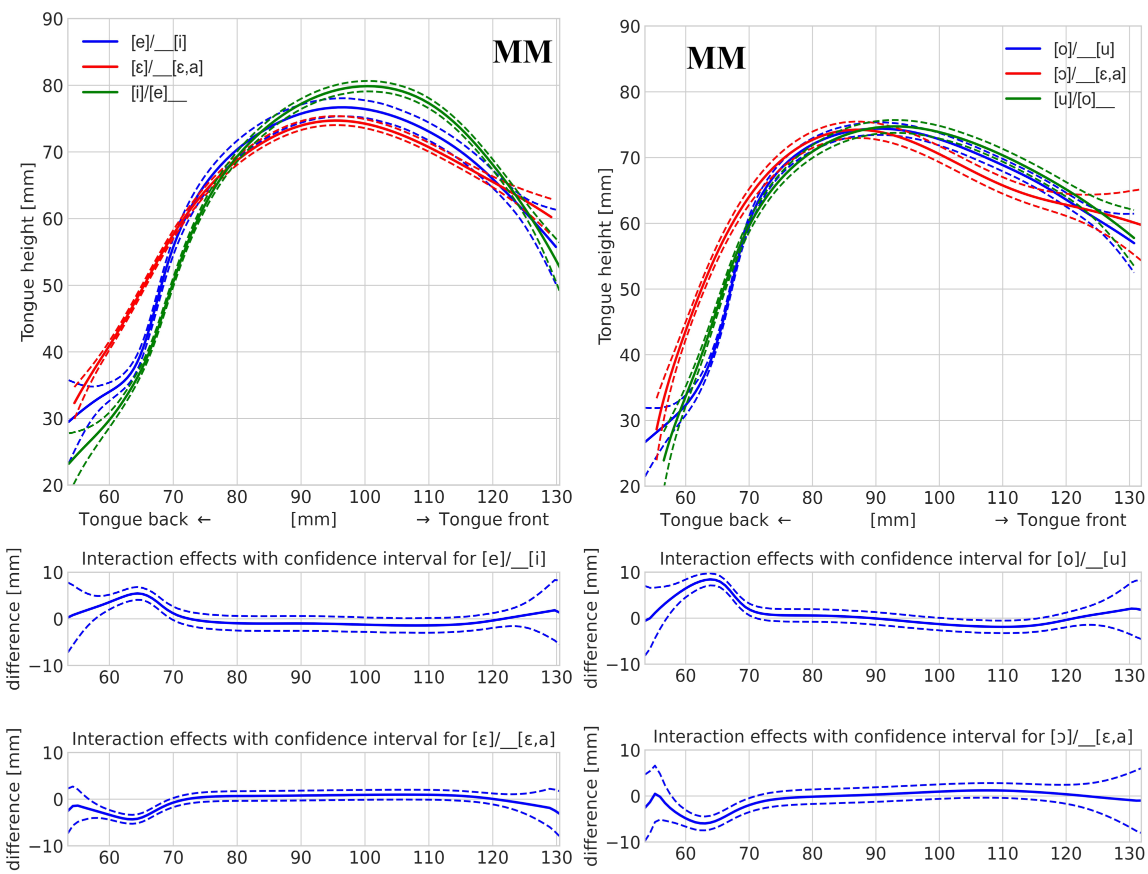

Figure 9: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in the subject MM: /ε/→[e]/__[i] on the left, /ɔ/→[o]/__[u] on the right.

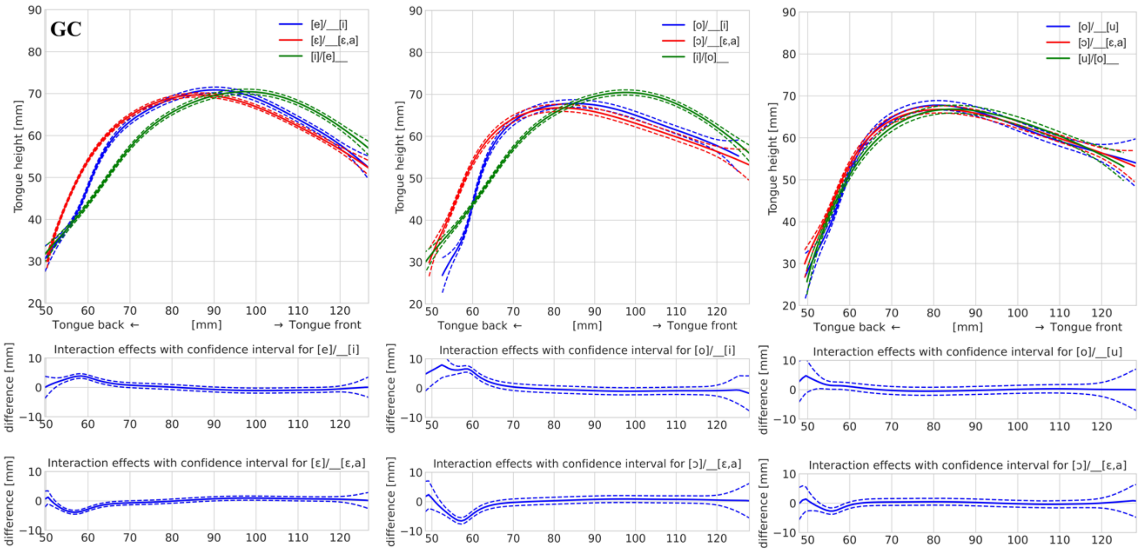

Figure 10: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in the GC subject: /ε/→[e]/__[i] top left, /ɔ/→[o]/__[i] top right, /ɔ/→[o]/__[u] bottom middle.

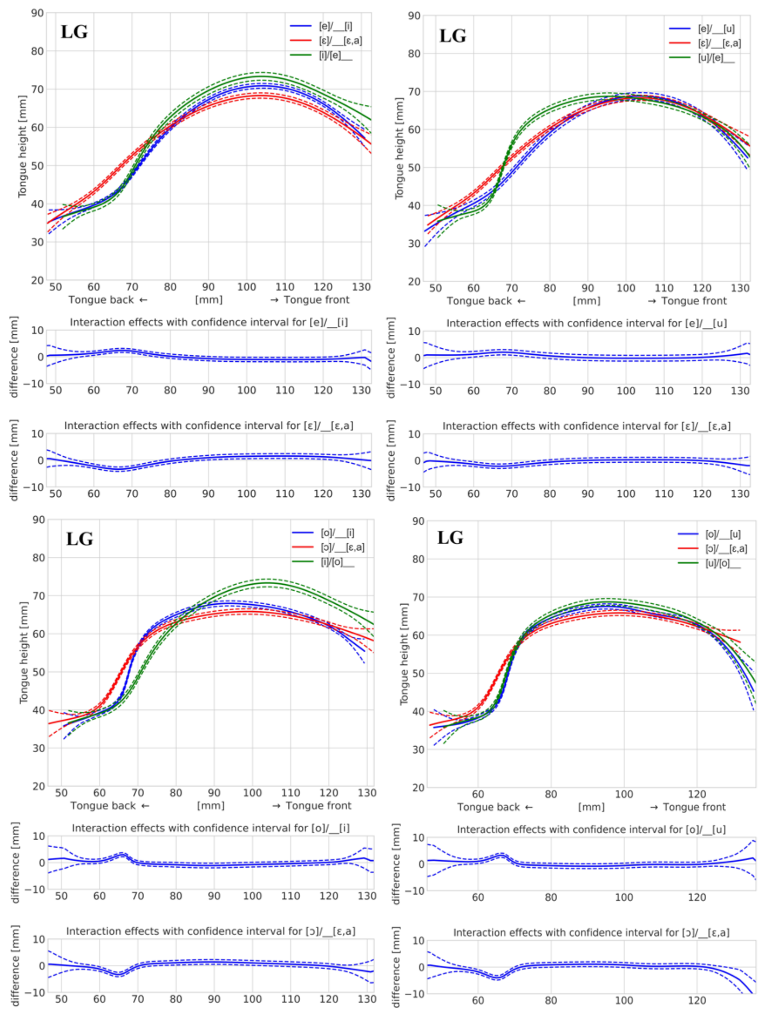

Figure 11: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in the subject LG: /ε/→[e]/__[i] top left, /ε/→[e]/__[u] top right, /ɔ/→[e]/__[u] bottom left, /ɔ/→[e]/__[u] bottom right.

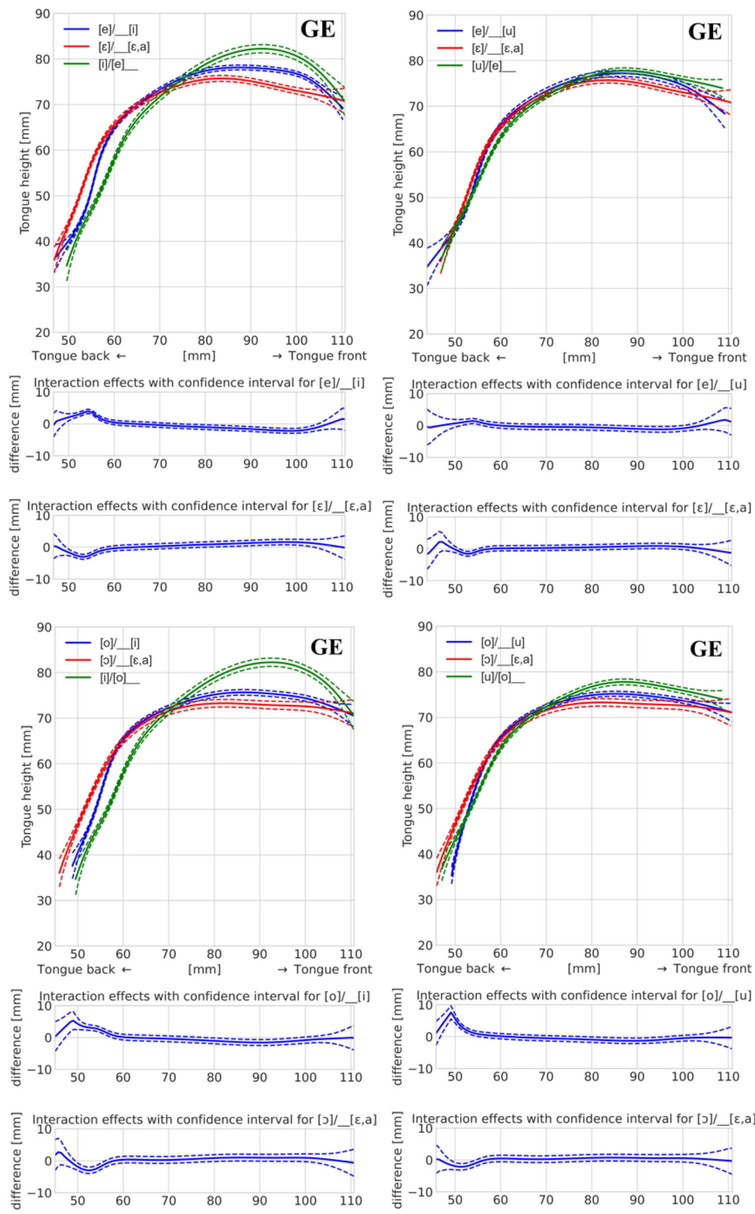

Figure 12: Tongue contours (top) and interaction effects with Bayesian confidence intervals (bottom) of the metaphonic pattern found in the subject GE: /ɛ/→[e]/__[i] top left, /ɛ/→[e]/__[u] top right, /ɔ/→[e]/__[u] bottom left, /ɔ/→[e]/__[u] bottom right.

A detailed interpretation of the data represented in Figures 8-12 is given in Table 1.

Subjects	Metaphonic patterns	Interaction effects Root Advancement	Interaction effects Dorsum raising	Acoustic effects
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
L.G. (m.)	/ɛ/→[e]/__[i]	*	/	Raising + Front
	/ɛ/→[e]/__[u]	*	/	Raising
	/ɔ/→[o]/__[i]	*(*)	/	Raising
	/ɔ/→[o]/__[u]	*(*)	/	Raising + Posterior
G.E (m.)	/ɛ/→[e]/__[i]	**	*	Raising + Front
	/ɛ/→[e]/__[u]	*	/	Raising
	/ɔ/→[o]/__[i]	**	(*)	Raising
	/ɔ/→[o]/__[u]	**	(*)	Raising + Posterior

Table 1: active metaphonic patterns for each Tricase speaker, significant articulatory interaction effects (with the anatomical parts of the tongue involved) and acoustic effects of the metaphonic patterns. ** = very significant; * = significant; an asterisk between parenthesis indicate that statistical significance is at limit; / = not significant. Cf. Tables 7-12 in the Appendix 2.

4. Preliminary discussion

4.1. Acoustic-articulatory properties of Southern Salentino metaphony

Overall, the findings of Experiment 1 suggest that the main acoustic correlate of the Southern Salentino metaphonic patterns is the lowering of the first formant (F1). From a purely acoustic point of view, the difference in metaphonic allophones is due to the difference of the values in Hz of the F1. In Figure 14, we represented the significant change in F1 relative to the conditionings of the triggers [i] and [u] on both targets /ɛ/, /ɔ/ for the male speakers LG and GE whose acoustic data are described in Figure 7. As that data shows, the metaphonic action does not produce 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. In contrast, the assimilation process generates two distinct allophonic categories both on the front and the back axis.

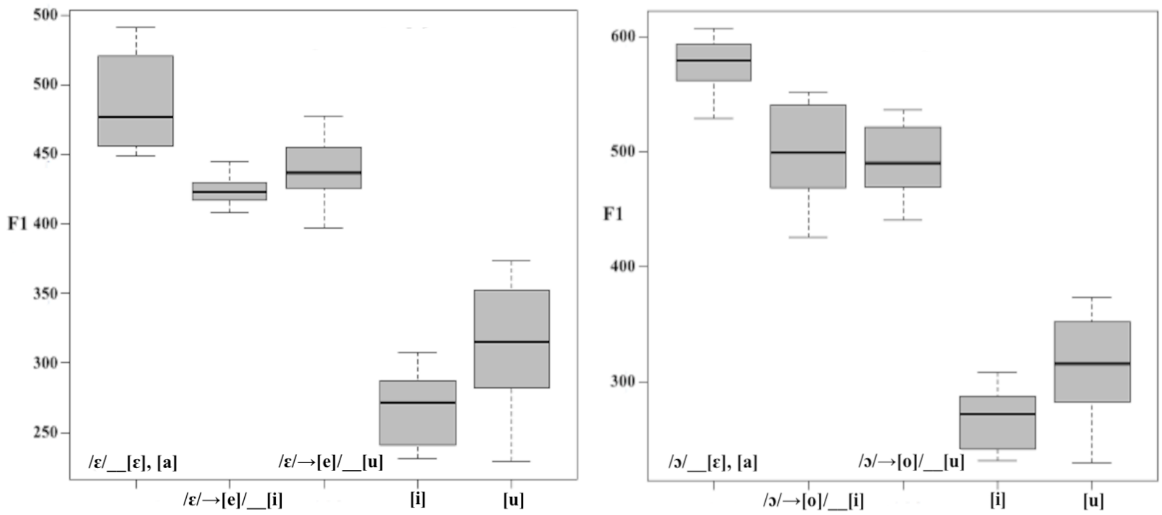

Figure 13: statistical distribution of the F1 Hz values related to the unstressed vowels [i] and [u] (triggering metaphony) concerning the LG and GE speakers. The metaphonic effects, /ɛ/→[e]/__[i], /ɛ/→[e]/__[u] on the left, and /ɔ/→[o]/__[i], /ɔ/→[o]/__[u] on the right are shown. Also, the no-metaphonic contexts, /ɛ/__[ɛ], [a] (on the left) and /ɔ/__[ɛ], [a] (in the right) are represented.

In line with previous data on Southern Salentino (cf. Section 1 and Figure 2), our findings highlight that the most common metaphonic patterns are the raising of /ɛ/ before [i] and the raising of /ɔ/ before [u], both of them extremely significant from a statistical point of view. Further corroborating previous data, we found that the less common metaphonic patterns are the raising of /ɛ/ before [u] (with a limited statistical level) and the raising of /ɔ/ before [i] (with a very significant statistical level). The generalized effect produced here by metaphonic assimilations is thus the raising of the allophonic variants in the acoustic space. Furthermore, as is shown in Figures 8-13 and Table 1, we found a very significant relationship between F1 lowering and tongue root advancement. Therefore, we propose that the allophonic contrasts [ɛ]-[e] and [ɔ]-[o] are generated by exploiting the [±ATR] feature. We also assume that this feature, in addition to [high] and [low], accounts for vocalic height contrasts. It follows under our analysis that this feature is behind distinctions such as tense/lax and close/open, which are often used to account for similar vocalic contrasts in the Romance and Germanic phonological literature. The next section is dedicated to the discussion of this issue.

4.2. The feature [ATR]

4.2.1 Acoustic correlates

As demonstrated by the data above, F1 lowering is the primary acoustic correlate of the ATR feature, such that [+ATR] vowels are realized higher than their [-ATR] counterparts in the acoustic space (Halle and Stevens 1969; Archangeli and Pulleyblank 1994; Guion et al. 2004; Maddieson 2003; Gick et al. 2006; Beltzung, Patin and Clements 2015; Kirkham and Nance 2017). Hence, F1 values are not only inversely related to tongue height—the more the tongue rises from the resting position, the more F1 values decrease—but also to tongue root advancement/non advancement. As Archangeli and Pulleyblank (1994: 7) put it: «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 have also been thought to play a role in [ATR] contrasts, although, according to Ladefoged (1968) and Lindau (1979), F2 values are not a consistent cue for [+ATR] differences in vowels. Front [+ATR] vowels tend always to be higher and more advanced in the acoustic space than the front [-ATR] vowels which are lowered and centralized (Halle and Stevens 1969; Ladefoged and Maddieson, 1996: 306). In the case of back vowels, in contrast, cross-linguistic variation is observed. In some languages, the back [+ATR] vowels have lower F2 than the [-ATR] ones, so that they are further back acoustically with respect to the [-ATR] ones that are centralized. For example, German displays lower F2 values both for [uː] and [o] than for their [-ATR] counterparts [ʊ] and [ɔ] (Hillenbrand et al. 1995; Jessen et al. 1998; Yang 1996; Stevens 2000; Bergmann et al. 2016; Kirkham and Nance 2017). Other languages have the opposite situation: in this case, it is the [-ATR] back vowels that have lower F2 values, so that they are further back acoustically than their [+ATR] counterparts. For example, this is shown for Niger-Congo varieties by Ladefoged and Maddieson (1996: 300-306) in their analysis of contrasts due to tongue root position (see the next Section for further discussion).

In Southern Salentino, the [+ATR] feature of the metaphonic vowel [e] appears to be correlated with F1 lowering ad F2 raising, which is in line with the cross-linguistic trends discussed above. This means that the [e] generated by metaphony is realized higher and more fronted than its non-metaphonized counterpart [ɛ]. Meanwhile, the mid-back [+ATR] vowel [o] produced by metaphony usually shows similar F1 lowering (Grimaldi 2009; Grimaldi et al. 2010), but, in contrast to [e], its F2 is lowered. This implies that more acoustic posterization, is involved, as discussed below.

4.2.2 Articulatory correlates

In articulatory terms, the basic correlate of the ATR feature obviously involves the presence or absence of tongue root advancement (Ladefoged 1968; Gick et al. 2006).[7] This articulatory gesture, however, 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 (9):

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

In fact, due to the tongue's hydrostatic properties (Kier and Smith 1985; Gilbert et al. 2007)—the tongue is an elastic mass—the tongue body shape is not completely independent of tongue root position. It follows then that in front [+ATR] vowels, tongue root advancement may lead to the bunching of the anterior part of the tongue. This produces a tighter-than-neutral curve to the tip/blade part of the tongue (Laver 1994: 142), and therefore a higher position of the tongue dorsum with respect to a front [-ATR] vowel. In [+ATR] back vowels, crucially full front dorsum advancement must be inhibited. However, tongue root advancement may still lead to a bunching of the back dorsum and a tighter-than-neutral curve, so that these back vowels may be higher and more posterior than their [-ATR] counterparts (see below for further discussion).[8]

Importantly, it seems that the correlation between tongue height and tongue root position varies among languages in distinguishing vowel contrasts. For instance, it has been shown that tongue height is not significantly correlated with tongue root position in West African phonological systems, such as Akan, Igbo, Dagbani, Twi, Kabiye, and Yoruba (Ladefoged 1968; Lindau 1979; Tiede 1996; Edmondson et al. 2007; Hudu et al. 2009; Hudu 2010; Allen et al. 2013; Kirkham and Nance 2017), as well as languages from elsewhere in Africa, such as Kinande, Maa, and Somali (Guión et al. 2004; Gick et al. 2006; Edmondson et al. 2007). In these varieties the advancement/non-advancement of the tongue root appears to be the basis of [ATR] contrasts, along with possible laryngeal and pharyngeal enhancing

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[7] Lindau's (1975) analysis of ATR contrasts in Akan has shown that tongue root advancement may also be associated with lowering of the larynx and further lateral expansion of the pharyngeal cavity (Lindau 1975, Stewart 1967; Ladefoged 1968; Lindau, Jacobson and Ladefoged, 1972; Painter 1973; Lindau 1979; Lindau-Webb 1987; Tiede 1996). This suggests that in these varieties, tongue root advancement, although the main articulatory gesture, is just one potential contributor towards the goal to generate [±ATR] contrasts.

[8] 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.

behaviors. On the other hand, the advancement of the tongue root is correlated with tongue height in English and German contrasts between tense and lax vowels (Ladefoged and Maddieson 1996; see also Kirkham and Nance 2017).

We suggest that this typological variation in [ATR] vocalic contrasts is due to a phonetic parameter involving inhibition or non-inhibition of tongue body bunching in the presence of tongue root advancement. If there is tongue body bunching inhibition, the relevant vocalic contrast is only due to the advancement/non-advancement of the tongue root. If there is no inhibition, the advancement/non-advancement of the root will result in tongue body dislocations, and therefore it will be correlated to tongue height differences.

Let us return to the issue of [ATR] contrasts occasionally correlating with F2 differences. It is plausible to assume that these differences are the result of tongue body bunching. Remember that in back vowels, bunching leads to a higher and more posterior position of the back dorsum, and therefore to a lowering of F2. As mentioned in the preceding section, variation in F2 values seem to occur only for the back vowels. In West African languages, the back [+ATR] vowels have higher F2 values than their [-ATR] counterparts, which are further back in the acoustic space. The opposite case is found in German, where the back [+ATR] vowels have lower F2 values than their [-ATR] counterparts, which are more centralized in the acoustic space. If there is a correlation between F2 changes and tongue bunching, this means that parametric variation in tongue body bunching is restricted to back vowels: some languages allow tongue bunching in the case of back vowels, others don't. This may account for the difference between West African languages and the Germanic languages. Only the latter group allows tongue bunching for [+ATR] back vowels, thus resulting in lower F2 for these vowels with respect to the [-ATR] back vowels. The reverse pattern characterizes African languages such as Akan, Igbo, Kinande, and others.

We suggest this as a baseline. This leads to the obvious question of why there should be an asymmetry between front [+ATR] vowels and their back counterparts: there is always tongue body bunching in the former but the same bunching is parametrized in the latter. We suggest that this asymmetry is due to the following: [+ATR] back vowels cannot allow full front dorsum advancement. If they did, they would become front vowels and miss their back acoustic target. Thus, bunching is either simply suppressed—the case of the West African languages mentioned above—or the bunching is controlled and pushed back so that only the back dorsum acquires a tighter-than-neutral curve. In this case, the back [+ATR] vowels are higher and more posterior than [-ATR] ones. The latter scenario describes case of German and the Romance languages.

There are a few complications that need to be mentioned. First, the high-back lax vowel [ʊ] in 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 observable for the mid-back lax vowel [ɔ], more steadily for British English than for American English. We suggest that this may be due to the direction of bunching. Even if controlled so that the back [+ATR] vowels do not become front, the bunching could lead to a more central or forward tongue body dislocation. This could be the source of the difference between English and German: English bunched-up [+ATR] vowels appear to be more forward than their German counterparts (see Ladefoged and Maddieson 1996).

On the other hand, recent work shows that even in some Niger-Congo varieties, F2 lowering occurs only in the case of the high [-ATR] vowels and not in the case mid [+back] [o]. Contrary to its high counterpart, this vowel exhibits more F2 lowering than [-ATR] [ɔ], which is then more centralized in the acoustic space (cf. Tiede 1996; Gick et al. 2006; Anderson Starwalt 2008). Assuming that this is not due to bunching occurring only in the mid vowels and not in the high ones, one could also suggest that advancement or non-advancement of the tongue root may have a smaller effect on F2 in the case of the mid vowel. Further research in these matters is required.

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

We begin by determining the properties of the assimilation process underlying Tricase metaphony. As mentioned above, the ultrasound imaging shows that the articulatory difference between mid-close and mid-open vowels involves Advancement of Tongue Root with possible body displacement (both in front and back vowels). In fact, the tongue dorsum tends to be raised, but this gesture does not always reach a systematic statistical significance. As discussed above, raising of the tongue dorsum is a result of tongue bunching caused by advancement of the tongue root. The advancement of the tongue root generates raising and anteriorization of [e] in the case of /ɛ/→[e]/__[i] (i.e., decreasing of the F1 values and increasing of the F2 values). It is noteworthy that the same forward movement of the tongue root generates no anteriorization of [e], [o] in the case of /ɛ/→[e]/__[u], /ɔ/→[o]/__[i]. Posteriorization of the allophone [o] in the case of /ɔ/→[o]/__[u] has been noted only for the speakers LG and GE (cf. Figures 8-13 and Table 1). This finding, however, will be strengthened by the results obtained from Experiment 2 (cf. Section 5.1.2, Figures 14-17 and Table 2).

Overall, Southern Salentino varieties appear to pattern with the Germanic languages from this point of view. Both in the case of the front and the back series, the vowels generated by the metaphonic process not only display an advanced tongue root but also tighter-than-neutral tongue curves. In the case of front vowels, the tongue dorsum is higher and more fronted; in the case of the back vowels the tongue dorsum is slightly higher and inclined to be further bunched backwards.

5. Experiment 2: testing intra-speaker microvariation

The data obtained from Experiment 1 showed that the microvariation patterns observed in Southern Salentino are also noticeable among different speakers of the Tricase variety. Experiment 2 tested if microvariation can also be found in the case of a single speaker.

5.1 Methods

5.1.1 Subjects and data acquisition

In a laboratory setting, we recorded the productions of three male speakers of the Tricase variety (mean age 42,6, SD 3,6): V.A., R.S., and M.M. None of these speakers were recruited for the Experiment 1. All the subjects presented the same sociolinguistic characteristics as the speakers previously investigated. In this experiment, the stimuli were represented by words and pseudo-words embedded in the carrier phrase used previously (cf. 2.1.1). We introduced pseudo-words here to investigate if the same microvariation patterns are also traceable when the consonantal context remains constant and semantic contents are nullified.

Both words and pseudo-words included the target metaphonic vowels /ɛ/, /ɔ/ in open and closed syllables: they were followed by the trigger vowels [i], [u] and the non-trigger vowels [ɛ], [a]. For the pseudo-words, the target vowels were surrounded by the bilabial consonant /b/ as its influence on the tongue body, dorsum, and root position is negligible: i.e., [ˈbɛba], [ˈbɛbɛ], [ˈbɛbu], [ˈbɛbi] and [ˈbɔba], [ˈbɔbɛ], [ˈbɔbu], [ˈbɔbi] for open syllables; [ˈbɛbːa] and so on for closed syllables). The word stimuli were the same as used in Experiment 1 (cf. Section 2.1.1). For each kind of vowels, 10 stimuli were elicited. The peculiarity of this experiment is that the three speakers produced twice the list of words and pseudo-words once, and then, again, an hour later. Thus, considering the three corner vowels (/i/, /a/, /u/) plus the three metaphonic/non-metaphonic contexts for each mid-stressed vowel (see (3)), 180 stimuli for each subject were elicited for a total 540 stimuli of both words and pseudo-words. The data were recorded and analyzed with the same procedure used for the Experiment 1 (cf. Section 2.1.1 and 2.1.2).

5.1.2 Results

In *Appendix 2*, Tables 13-24, the mean F1/F2 values in Hz of the Tricase stressed vowels /i/, /u/, /a/ and the stressed /ɛ/ and /ɔ/ vowels, distinguished according to their context, are given for words and pseudo-words. In Tables 25-36 the results of the independent t-tests are illustrated (the asterisks indicate the levels of statistical significance found in comparing the F1/F2 Hz values of couples of vowels potentially affected by metaphony). The data in Tables 25-36 are represented in Figure 14 below.

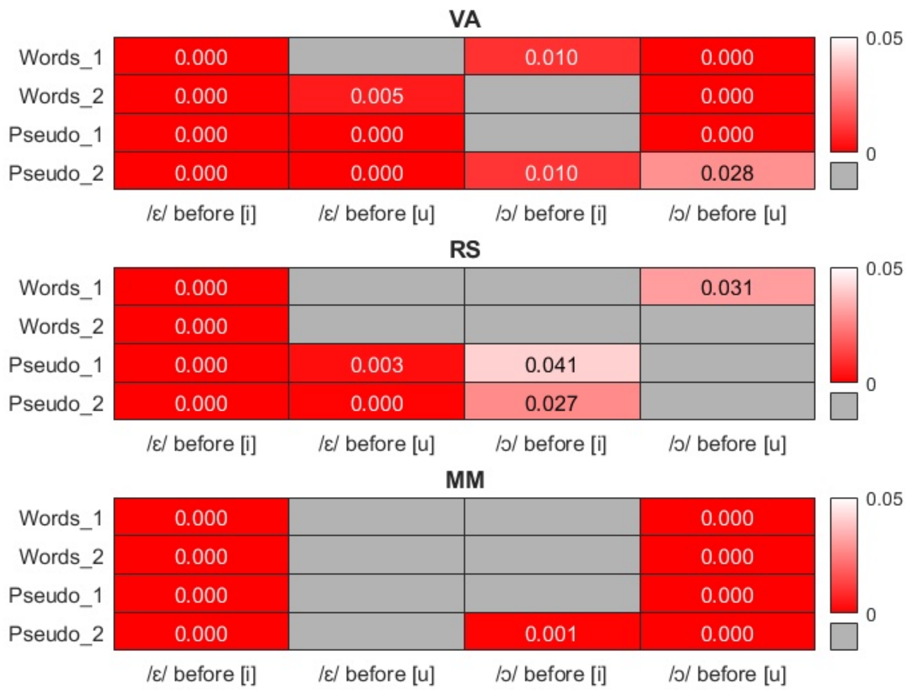

Figure 14: Different metaphonic action of unstressed [i] and [u] on the preceding stressed /ɛ/ and /ɔ/ vowels for the VA, RS, and MM speakers. On the vertical axis: words and pseudowords repetitions. On the horizontal axis the metaphonic contexts /ɛ/ before [i], /ɛ/ before [u], /ɔ/ before [i], and /ɔ/ before [u]. The levels of statistical significance are represented in each column with different shades from red (extremely significant level) to white (significant level). Gray = not significant.

In Figures 15-17 the /i/, /a/, /u/ vowels together with the allophonic variants of the mid-vowels /ɛ/, /ɔ/ produced by the three speakers within words and pseudo-words are plotted in a two-dimensional F1-F2 Hz space by using ellipses on data.

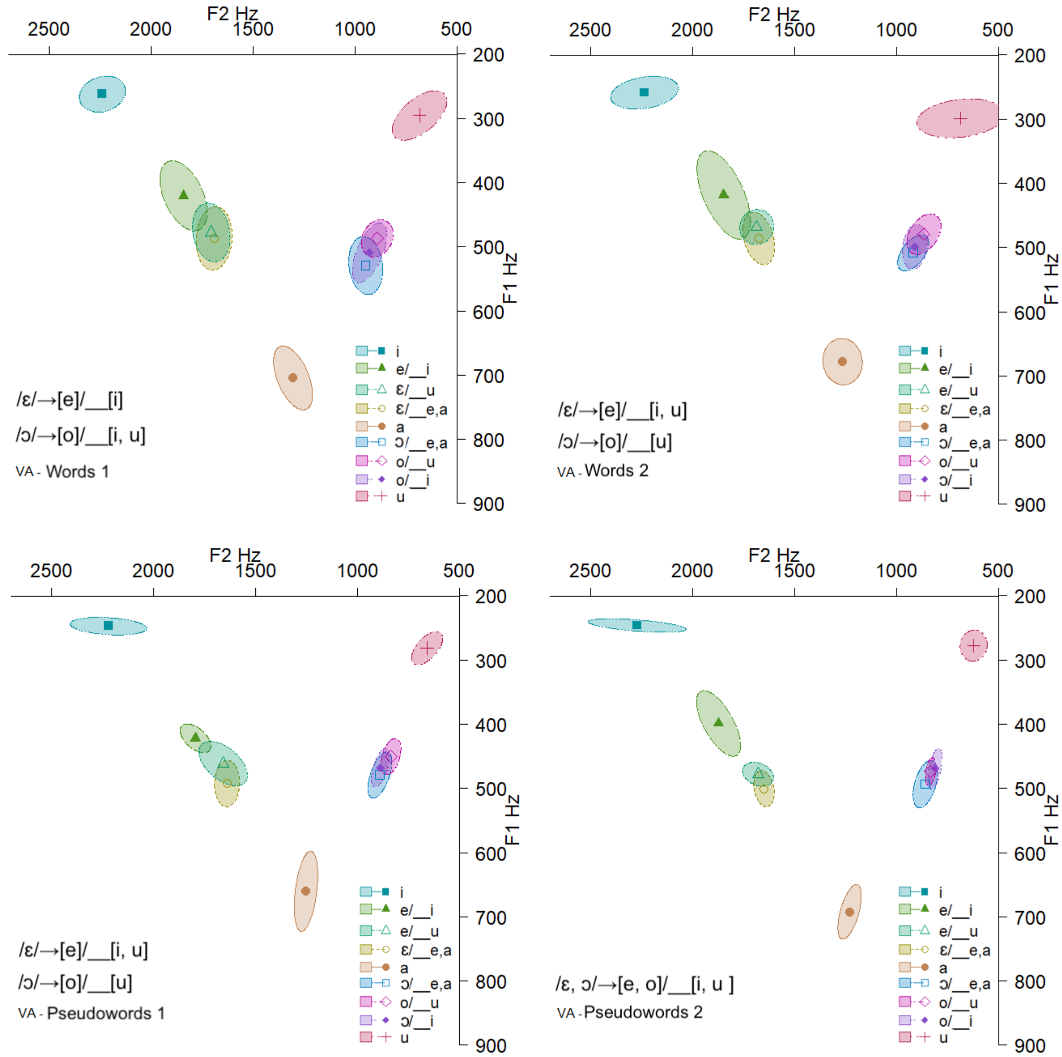

Figure 15: Scatter plots based on F1 and F2 Hz values of the vowels twice produced both within words (at the top) and pseudo-words (at the bottom) by the VA subject. Significant metaphonic adjustments of mid vowels /ɛ/, /ɔ/ are shown. Each ellipse encompasses 68,8% of data points for one vowel category. The data from the first elicitation of the words and pseudowords are on the left, the second elicitation data is on the right.

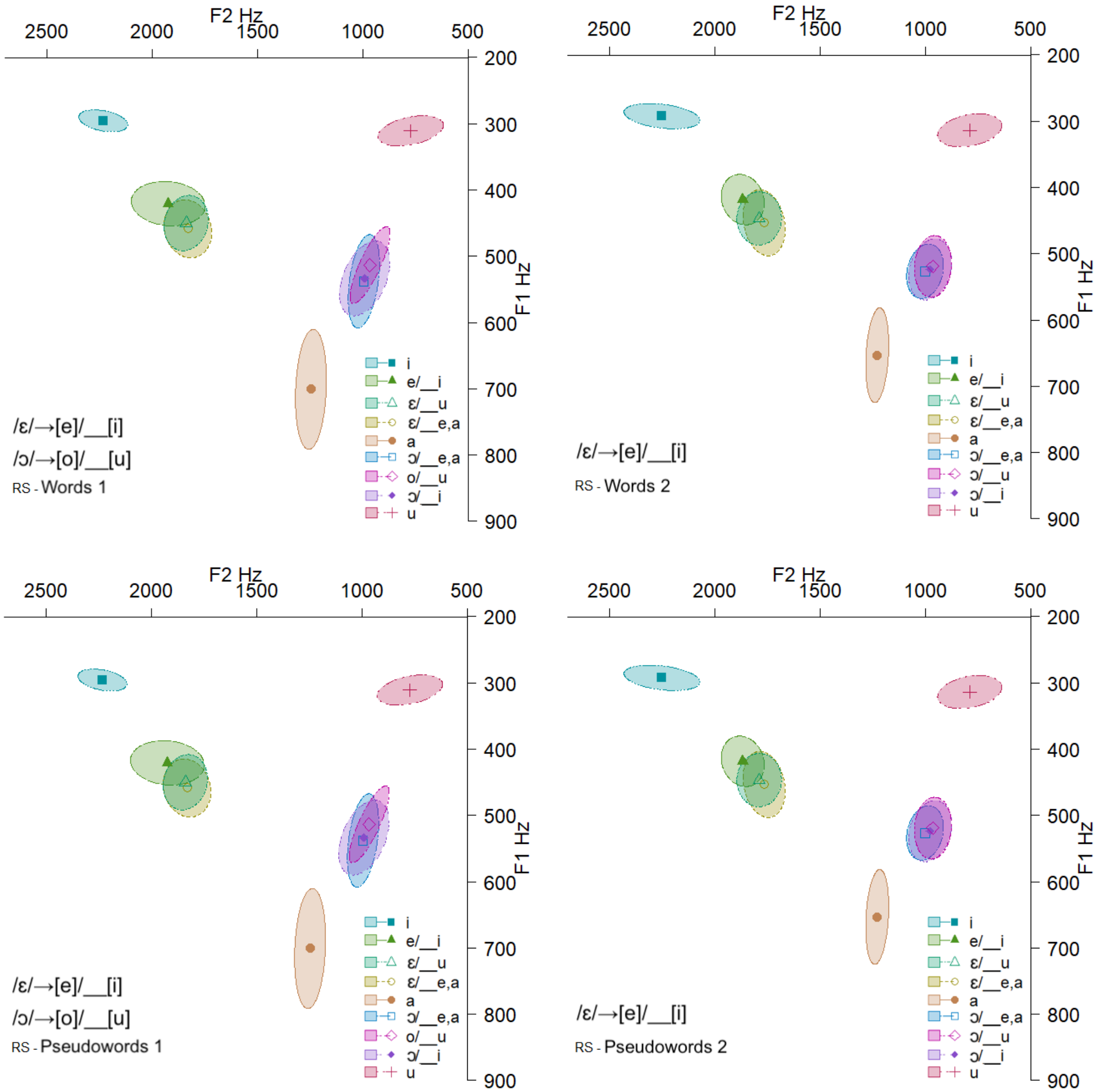

Figure 16: Scatter plots based on F1 and F2 Hz values of the vowels twice produced both within words (at the top) and pseudo-words (at the bottom) by the RS subject. Significant metaphonic adjustments of mid vowels /ɛ/, /ɔ/ are shown. Each ellipse encompasses 68,8% of data points for one vowel category. The data from the first elicitation of the words and pseudowords are on the left, the second elicitation data is on the right.

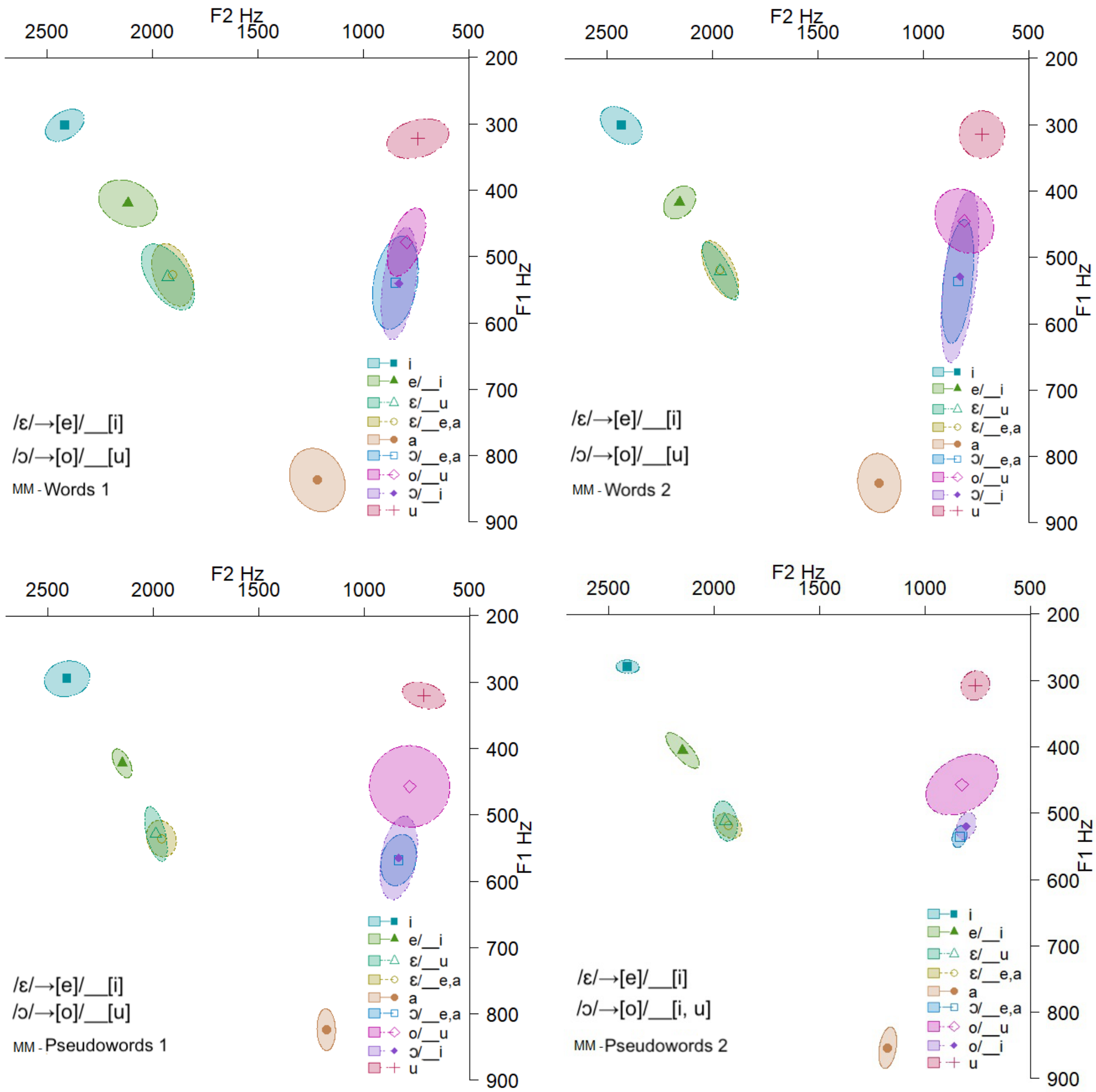

Figure 17: Scatter plots based on F1 and F2 Hz values of the vowels twice produced both within words (at the top) and pseudo-words (at the bottom) by the MM subject. Significant metaphonic adjustments of mid vowels /ɛ/, /ɔ/ are shown. Each ellipse encompasses 68,8% of data points for one vowel category. The data from the first elicitation of the words and pseudowords are on the left, the second elicitation data is on the right.

The data represented in Figure 15-17 are synthetically described in *Table 2*:

Subjects	Metaphonic contexts	Significant Metaphonic Patterns and Acoustic effects			
		Word_1	Word_2	Pseudo_1	Pseudo_2
V.A	/ɛ/ before [i]	* Raising+Fronting	* Raising+Fronting	* Raising+Fronting	* Raising+Fronting
	ɛ/__u	/	* Raising	* Raising	* Raising+Fronting
	ɔ/__i	* Raising	/	/	* Raising+Posterior
	ɔ/__u	* Raising+Posterior	* Raising+Posterior	* Raising+Posterior	* Raising+Posterior
R.S.	ɛ/__i	* Raising+Fronting	* Raising+Fronting	* Raising+Fronting	* Raising+Fronting
	ɛ/__u	/	/	* Raising	* Raising
	ɔ/__i	/	/	* Raising	* Raising+Posterior
	ɔ/__u	* Raising+Posterior	/	/	/
M.M.	ɛ/__i	* Raising+Fronting	* Raising+Fronting	* Raising+Fronting	* Raising+Fronting
	ɛ/__u	/	/	/	/
	ɔ/__i	/	/	/	* Raising+Posterior
	ɔ/__u	* Raising+Posterior	* Raising	* Raising	* Raising

Table 2: metaphonic patterns found in words and pseudo-words twice produced by three Tricase speakers. The asterisk indicates a significant effect. / = not significant. Cf. Table 25-26 in the Appendix 2.

5.2 Intra-speaker microvariation

Experiment 2 demonstrated the variability of metaphonic patterns even for the same speaker. There is no pattern stability in the production of each speaker; they manifest varying patterns both for words and pseudo-words, showing an unstable grammar. In essence, the metaphonic process is not fixed for any of speakers. Despite this, we can observe some generalizations.

Crucially, Experiment 2 highlights that the metaphonic patterns found for intra-speaker variation agree with the findings of earlier investigations: both Grimaldi (2003), where just one speaker for each locality was recorded and Experiment 1 (cf. Figure 6, Table 1), where different speakers of the same locality were analyzed. These results are relevant because they were obtained also when pseudo-words were used: that is, with consonantal contexts well controlled so that they could not affect the assimilatory process.

In particular, it has been once more confirmed that: (1) [i] is a systematic trigger that preferably affects /ɛ/; (2) [u] is not a systematic trigger unless the target is /ɔ/. Again, the more typical metaphonic patterns resulted in /ɛ/→[e]/__[i] and /ɔ/→[o]/__[u]. According to the data discussed above, [i] may exceptionally also target /ɔ/, and [u] may exceptionally target /ɛ/, but the statistical significance is reduced (cf. Figure 15). Altogether, our findings suggest that back vowels behave differently: it seems that back vowels have a special status in the Southern Salentino system.

The Experiment 2 allowed us to better observe the effects of the metaphonic process on the F2 values. As already discussed, a strong effect is the increasing of the F2 values for the /ɛ/→[e]/__[i] pattern; so, the allophonic variant [e], both in words and pseudo-words, is raised and advanced in the acoustic space. The allophonic variant generated by [u] (/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. The allophonic variant [o] originated by the influence of [u] is more raised and posteriorized, and therefore more external in the acoustic space than the not-assimilated counterparts. Following Ladefoged (1968) and Lindau (1979), our data suggest that changes in F2 values do not constitute a steady cue for [+ATR] vowels (cf. Section 4.2.1).

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

6.1 Diachronic perspective

Metaphonic processes affecting stressed mid-vowels followed by high vowels characterize all Southern Italian varieties (for a discussion on metaphony in Italy and Romance see Savoia 2015 and Calabrese 2011). Historical and comparative evidence shows that metaphonic alternations arose in the early Middle Ages, and became stable features of the phonology of these varieties in the later centuries (cf. Maiden 1991).[9] In many of them, neutralization, or even disappearance, of the final vowels lead to the morphologization of these processes where suffixal high vowels realize inflectional features such as plural number, or second person singular in the case of unstressed [i]. Because of the neutralization or loss of these vowels, the only surface markers for these categories were the metaphonic alternants (see Calabrese 2016).

Let us now focus on these processes as found in the closest varieties to Southern Salentino: that is, Northern and Central Salentino. Comparative evidence from other dialects shows that the metaphony system of Northern Salentino developed from a system of the "Neapolitan" type. Varieties of this type are characterized by the common Romance seven vowel system:/ i, e, ɛ, a, ɔ, o, u/. In this system, mid-high vowels are always raised to high before a high vowel, whereas mid-low vowels in the same context may be diphthongized. This results in alternations such as in the examples [ˈpeʃːe]/[ˈpiʃːi] *fish* sg/pl, [ˈpɛte]/[ˈpjeti] *foot/feet*, where the plural masculine form shows metaphonic effects. We assume the analysis proposed by Calabrese (1984, 1998) for this metaphony system. It entails the spreading of the high vowel feature [+high] onto the mid-stressed vowels; this directly accounts for the raising of the mid [+ATR] vowels to high. The illicit [+high, -ATR] outcomes generated in the case of mid [-ATR] vowels were further repaired by fission, which lead to diphthongization.

Eventually, the distinction between mid-high and mid-low vowels was lost evolving in a five-vowel system, /i, ɛ, a, ɔ, u/, which led to a lexicalization of the metaphonic alternants, as in the dialect of Francavilla Fontana: [ˈpeʃːi]/[ˈpiʃːi] *fish* sg/pl, [ˈpɛti]/[ˈpjeti] *foot/feet* (note also the neutralization of the final unstressed vowel into high ones). The Central Salentino vowel system is different from the Northern one, insofar as mid-high vowels merged with the high ones across the board so that there are only alternations in the case of the mid-low vowels, as in Campi: [ˈpiʃːɛ]/[ˈpiʃːi] *fish* sg/pl, [ˈpɛti]/[ˈpjeti] *foot/feet*.

Let us now turn to Southern Salentino varieties. Note that they share with the Central varieties the merger of mid-high vowels with high vowels. Traditional descriptions dealing with these varieties (Parlangeli 1953; Rohlfs 1966; Stehl 1988; Mancarella 1998) state that they are not characterized by metaphonic phenomena. In fact, a careful phonetician like Gerhald Rohlfs does not report any metaphonic alternations for these varieties in his field-work 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. [ˈpɛte/ˈpeti] *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: e.g., [ʃenkaˈreɖːu]/[ʃenkaˈreɖːi] m. *calf/calves*.[10]

In order to explain this inconsistency between the traditional description of Southern Salentino varieties and the findings of this work and Grimaldi (2003), we would like to suggest that the spreading of metaphonic alternations in Southern Salentino varieties is a quite recent development. It is supported by the inter-speaker and intra-speaker variation we observe in the varieties to be discussed in more detail in the next Section. We also assume that it developed independently of the classical metaphony of the

[9] For a different perspective see Loporcaro (2016).

[10] 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 (cf. Figure 1). The author attributed the forms to idiosyncratic variability of the speakers and not to peculiar phenomena of these varieties: i.e., [ˈservi] *domestics*, [ˈbːonu] *good* (adj. sing. m.), [ˈmorju] *I die*, etc.

more Northern Italo-Romance varieties, most probably in the last century, thus clearly more recently than classical metaphony whose origin can be dated back to the early Middle Ages (Maiden 1991).[11]

6.2 Synchronic perspective

A crucial issue to address is now the nature of the variation we observe in Southern Salentino. Linguistic vaiation can stem from many possible sources and can be multidimensional. One possibility is sociolinguistic diversity: speakers of different social backgrounds speak differently, and all speakers vary in speech style and register. The variation we observe in Tricase cannot be accounted for in terms of sociolinguistic variability. We controlled sociolinguistic and parental backgrounds of all the speakers in our study and were unable to correlate any social variable to their different metaphonic patterns. Additionally, the age and level of education of the speakers in Grimaldi's (2003) study and our study cannot explain the metaphonic variations. In fact, the subjects recorded by Grimaldi's (2003) investigation were, on average, 70 years old (illiterate or with primary education), while the speaker investigated by Grimaldi et al. (2010) was 54 years old (college degree), and the subjects involved in the Experiments 1 and 2 were, on average, 21 years old (university students) and 42 years old (college degree), respectively. Thus, the evidence, together with the findings discussed above, strongly suggest that the microvariation patterns are not subjected to sociolinguistic constraints. This is confirmed by Experiment 2, which demonstrates that the same variation may be found in the same speaker pointing to a variable realization devoid of social meaning.

Variability could also arise at the acoustic and articulatory level. For example, vowels are variable in realization. As Peterson and Barney (1952) showed, a vowel cannot be defined as an articulatory point, or as a particular acoustic realization, but rather as a region in articulatory and acoustic space; thus, measurements of a speaker producing a given vowel may show considerable scatter in this range, and produce items that fall outside it. But this variation is essentially random, and cannot account for the existence of clearly defined (though still variable) metaphonic patterns across our speakers, and even in the same speaker.

A third factor in variability is simple optionality: some phonological processes may or may not occur in the same (specific) circumstances. However, the different variable patterns we observe in the Tricase speakers cannot be adequately accounted for in terms of an optional application of a given process.

Another potential source of variation can be found in emergent gradient phonetic processes or developing phonological phenomena that have not reached normative status across members of a social group or community. First, variation arises due to acoustic, perceptual and articulatory constraints on speech. In this way, phonetic entities can be pronounced in different ways, depending on the environment. These variable patterns are universal and beyond human cognitive control. These gradient variable patterns may be phonologized. In phonologization, a variable pattern which was caused by extra-grammatical factors is somehow analyzed by speakers as both involving a new language specific generalization and also generating stable phonological categories. As a consequence, this generalization will be cognitively controlled and internalized in the grammar (Kiparsky 2006; Bermúdez-Otero 2103; Bermúdez-Otero and Trousdale 2012). 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 condition under which this occurs). So, the phonologization of a certain pattern leads to phonological innovation. Some innovations spread, while others do not. Phonological change occurs as it spreads from the innovators to other members of a social groups where it will be accepted by early adopters, then diffuse to still other members. During this process of diffusion, there will be natural variation. Gradually, the variation involved becomes orderly and the variants may

[11] 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 (forthcoming).

acquire social meaning. If fully successful, it will become a normative phonological aspect of the variety of some community, or social group (Labov 2001, 2010, 2014a,b; Bermudez-Otero 2020). We would like to suggest that this last step has not yet fully occurred in the case of Southern Salentino metaphony.

First of all, let us consider the possibility that this study is not showing the emergence of new variation, but is instead capturing universal V-C-V coarticulatory patterns that are perhaps always characteristic of vowel sequences in five vowel systems. If this were correct, these patterns should be universal, at least in five vowel languages. The fact that there are Southern Salentino varieties that appear not to have any metaphonic alternations at all excludes this possibility. The processes are language specific, so speakers must be able to learn the phonological rules controlling 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, Grimaldi and Calabrese 2013). In this work, we ascertained whether the allophonic variants [e], [o] and the phonemes /ɛ/ and /ɔ/ were processed in different ways by the auditory system of these speakers. The behavioral and electrophysiological responses obtained from 12 Tricase speakers suggested that both allophones and phonemes were equally categorized in early speech processing and 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/non-contrastive status of the sounds as determined by the listeners' knowledge of the phonological system. Given these results, we argued that Southern Salentino metaphony must have a cognitive reality. It follows that Southern Salentino metaphony has at least undergone phonologization. It is a language-specific and cognitively controlled generalization learned by the speakers of Southern Salentino varieties.

This generalization is over discrete categories in the phonetic surface, which are realizing phonological representations. As pointed out above by Bermudez-Otero and Trousdale (2012) stabilization of a gradient phonetic process into such a generalization is demonstrated by consistent bimodal distribution of output tokens of this process (see also Scobbie 2005)[12]. This type of bimodal distribution is precisely found in the outputs of Southern Salentino metaphony across the speakers that were investigated in the study, as clearly exemplified in Figure 14. Looking at the significant harmony effects on the F1 Hz values, it is clear that both unstressed [i] and [u] harmonize [ɛ] and [ɔ] generating the [e] and [o] allophones. We can easily notice how the outputs generated by the metaphonic assimilation manifest a clear bimodal distribution where discrete allophonic categories reflect the application of a phonological rule (as discussed in Section 4.1).

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. Furthermore, we would then like to 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 do not have access to a norm on how it should work. This allows for the variation as accounted for below.

7. Phonological analysis

We now need to deal with the issue of the varying metaphonic patterns. What are the interacting parameters and restrictions that control the spreading of the feature/s generating the microvariation, and how can a phonological model capture this process?

First of all, one needs to determine the characteristic properties of the assimilation process underlying Southern Salentino metaphony. As already discussed, the ultrasound imaging of the vocal

[12] Statistically, a bimodal distribution is a frequency distribution of data with two distinct modes, which, usually, indicates that we are in front of two different entities.

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. In both front and back metaphonic vowels, there is also tongue body bunching. In the case of front vowels, the tongue body is bunched up forward. In the case of back vowels, it is bunched up backwards. In both cases, the metaphonic mid vowels are slightly higher. It is interesting to notice that this effect appears to be more pronounced when the trigger and the target vowel belong to 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 turn to an account of the variation we observe in case of Southern Salentino metaphony. As mentioned above, the preferred target of this process is [ɛ]. In many varieties, it is the only target of the phenomenon. Back [ɔ] is never the only target, unless followed by [u]. Thus, there are speakers that have only /ɛ/→[e]/__/i/ or /ɛ/→[e]/__[i], [u] but there are no speakers that have only /ɔ/→[o]/__/i/, or /ɔ/→[o]/__[i], [u].

At the same time, [i] is the most common Southern Salentino metaphony trigger. The /ɛ/→[e]/__/i/, metaphonic pattern is generally characterized by extreme or very significant statistical levels. Furthermore: [i] is often the only trigger of the process whereas [u] is never found in this situation unless the target is /ɔ/. There is no variety where changes such as /ɛ/→[e]/__[u] or /ɛ, ɔ/→[e, o]/__/u are the only metaphonic patterns. Therefore, there is a clear asymmetry between final [u] and final [i] with respect to their being trigger of the phenomenon.

Final [u] is preferably not a metaphony trigger and stressed [ɔ] preferably is not a metaphony target. The only exception is the pattern [ɔ]→[o]/__[u], which together with /ɛ/→[e]/__[i] is also characterized by very significant statistical level. Note that harmony systems in which a target segment assimilates a feature from a trigger segment only when they share another feature are well attested (Steriade 1981, Cole and Trigo 1988, Nevins 2010). They are called parasitic harmony systems. A famous case is Yokuts rounding harmony: /i/→[u]/__[u], /a/→[o]__[o], where vowels are rounded only in front of rounded vowels of the same height. We will call the Southern Salentino pattern /ɛ/→[e]/__[i], /ɔ/→[o]/__[u], back-based parasitic metaphony.

We propose that the different metaphonic alternations observed in Southern Salentino involve processes of [+ATR] assimilation. In the most general process as described in (1), both [i] and [u] can trigger metaphony for either mid vowels. This process, given in (7), can be accounted for by the rule in (8) (where [* indicates that the vowel carries main stress, N=syllabic nucleus, X=skeletal position):

(7) /ɛ, ɔ/→[e, o]/__[i, u] (Area F, Tricase 1 LG, GE, Tricase 2 VA)

(8)
[*
N N
X X
[-cons] [-cons]

[-low] [+ATR]

The issue is to account for the microvariation we observe across local varieties, in the same variety, and in the same speaker. As mentioned above, note that in some cases [u] is not a possible trigger and that in other ones [ɔ] is not a possible target. The special behavior of the back vowels can be accounted for as follows. Recall the conclusion from Section 4.2.2, in realizing [+ATR] back vowels, speakers need to suppress the natural tendency to front them. The need for this suppression makes the configuration [+ATR, +back] articulatorily complex, and therefore phonologically marked. The marking statement in (10) expresses this complexity:

(10) *[+back, +ATR]

If this constraint is active (high ranked in OT terms),[13] 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 (11):

(11) /ɛ/→[e]/ __ [i] (Area A, Tricase 1 M.B)

Let us suppose that height may play a role in this constraint so that we can distinguish two versions of it as in (12):

(12) a. *[+back, +ATR]/[____+high]
b. *[+back, +ATR]/[____-high]

The combined effect of the activity of (12a) and (12b) would parallel what happens with (10). If only one of them is active, one has the following situations. If only the constraint in (12a) is active, the high vowel must be [-ATR] and cannot be a trigger; the process however can target mid-low /ɔ/. The resulting situation would be that in (13):

(13) /ɛ, ɔ/→[e, o]/__[i] (Area D)

If the constraint in (12b) is active but the one in (12a) is not, [u] can be a trigger but /ɔ/ not a target, so we would have (14):

(14) /ɛ/→[e]/__[i, u] (Area B)

Thus, the general rule in (8), interacting with the constraints in (12), could account for some of the variability we observe in Southern Salentino metaphony. However, we still need an account for parasitic metaphony. In this regard, we can consider the assimilatory pattern in (11) again: /ɛ/→[e]/ __ [i]. This

[13] One of the authors is not an OT practitioner so we don't adopt an OT theoretical framework in our analysis. The crucial idea is that an active constraint may block the application of a rule. How the notion of blocking is implemented is irrelevant (see Calabrese (2005, 2019) on his way of accounting for it).

pattern is the most statistically stable one across the varying systems and could be considered the simplest pattern from the markedness point of view, insofar as the constraint in (12) are fully respected. One could also hypothesize that this is historically the most basic pattern. Let us assume that it may be analyzed as involving a linked [-back] as expected in a non-linear framework as in (15):

(15)
```
      N          N
      X          X
   [-cons]    [-cons]

   [-back]
              [+ATR]
```

One can assume that this analysis may also lead to a reanalysis of the metaphonic process triggered by back vowels as being parasitic on the feature [+back], as in (16):

(16)
```
      N          N
      X          X
   [-cons]    [-cons]

   [+back]
              [+ATR]
```

Support for (15) or (16) is provided by the fact that either of them can apply together with the more general (8). Being more specific, they would take precedence over the application of (8), thus bleeding it, in the relevant cases because the elsewhere principle. If (15) applies with (8), we obtain the situation in (17):

(17) /ɛ/→[e]/__[i] (by (15)) & /ɛ, ɔ /→[e, o]/__ [u] (by elsewhere application of (8))
(Area F, Tricase 2 VA)

If (16) applies with (8) we obtain the situation in (18):

(18) [ɔ]→[o]/__[u] (by (16)) & /ɛ, ɔ/→[e, o]/__[i] (by elsewhere application of (8))
(Tricase 2 MM)

If (15) and (16) apply together, as represented in (19), we would obtain the situation in (20). This can be considered a general instance of parasitic metaphony. This appears to be the most frequently attested process across the Tricasino speakers and in the Southern Salentino varieties:

(19)
```
      N          N
      X          X
   [-cons]    [-cons]

   [αback]
              [+ATR]
```

(20) /ɛ/→[e]/__[i], /ɔ/→[o]/__[u] (Area E, Tricase 1 CR, Tricase 2 MM RS, MM)

There could also be concomitant articulatory/acoustic factors that favored the formal reanalysis just proposed. Observe in fact the effects of the metaphonic assimilations on the F2 values: a strong effect is the increasing of the F2 values for the /ɛ/→[e]/__[i] pattern; the allophonic variant [e] is raised and advanced in the acoustic space. Conversely, in the case of the mid-back vowels before [u], there is F2 lowering so that the vowel is acoustically more posteriorized, and therefore more external in the acoustic space than the non-assimilated counterpart [ɔ].

The allophonic variants [e], [o] also have two asymmetrical grades of height, correlated with differences in F2 values. (cf. Figure 5; Tables 1-12 in the *Appendix 2*) Their height depends on the trigger that generates metaphonic assimilation: on the front axis, [e] before [i] resulted higher than [e] before [u], while on the back axis [o] before [u] resulted higher than [o] before [i].

We suggested that these articulatory behaviors are due to 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 associated with a synergetic interaction between the bunching gesture in the trigger and the target. The bunching of the target may increase as a result. This would account for the acoustic effect noted above: i.e., the fact that the [i], [u] triggers determine two asymmetrical grades of height of the allophonic variants [e], [o] (see Section 4.3)). We suggest that these acoustic-articulatory patterns encouraged the reanalysis proposed above in (17).

Given the statistical status of parasitic metaphony across Southern Salentino varieties as the most frequent pattern, we also suggest that parasitic harmony is now the primary phonological innovation spreading across Southern Salentino speakers. We thus have an account of all the possible metaphony patterns we observed in these varieties and of their variation.

8. Conclusions and further remarks

Contrary to other widely studied harmony processes, Southern Salentino metaphony is characterized by instability: metaphonic patterns in words and pseudowords display microvariation both in inter-speaker and intra-speaker conditions. The available data led us to exclude that the observed variation is due to sociolinguistic factors (cf. Section 6.2.) insofar as the variation cannot be correlated with any social variables. Instead, we suggest that our investigations have captured an on-going linguistic change that has not yet been completely normativized in the speech of these communities. We hypothesize that the Tricase situation, which may perhaps be the common situation across Southern Salentino, indicates that none of the possible variants of the metaphony process have acquired socially normative status. Therefore, the process has not been fully grammaticalized as a feature of the linguistic system. Learners of a given speech variety—that of Tricase, in this case—have acquired the knowledge that there is a process of harmonic assimilation that spreads the feature [+ATR] of the final high vowels onto the preceding stressed mid vowels. It could be parasitic metaphony in (17) or it could take the shape of the more general (8). In both cases, the processes are interacting with the active constraints in (12) in the ways postulated above. However, given the absence of an established grammatical norm, speakers are still exploring how this process works. We suggest that it is this that generates the variation that we observe in this phenomenon. If this is correct, it also follows that Southern Salentino metaphony must have developed only recently (*contra* Loporcaro 2016, who assumes it to be already active in early medieval times). Future research is needed to establish if this variation is found across all Southern Salentino communities or if there are varieties where the grammatical variation has stabilized, i.e., where grammatical norms have emerged.

Declarations of interest:

The authors declare that the research was conducted in the absence of any competing financial, commercial and nonfinancial interests that might be perceived to influence the results and/or discussion reported in this paper.

Credit author statement

Andrea Calabrese: Conceptualization, Methodology, Investigation, Supervision, Validation, Writing - original draft, Writing – review & editing.
Mirko Grimaldi: Conceptualization, Methodology, Investigation, Supervision, Resources, Validation, Software, Visualization, Writing - original draft, Writing – review & editing.

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