ON THE PHONETIC BASES OF VOWEL-CONSONANT COORDINATION IN ITALIAN : A STUDY OF STRESS AND "COMPENSATORY SHORTENING"

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ABSTRACT

This study focuses on the temporal organization of consonants and vowels in Italian, ostensibly a syllable-timed language. It aims to reveal the articulatory origins of a class of acoustic shortening phenomena known as "compensatory." We compared durations and first formant trajectories of /a/ in two compensatory contexts: 1) stressed /a/ in open *vs.* closed syllables; 2) stressed /a/ followed by one or two unstressed syllables. In addition, we measured /a/ in a prosodically different shortening context: stressed *vs.* unstressed position. We found that in Italian (as in English) shortening of a vowel before a tautosyllabic consonant is due to truncation by the *closing gesture* for the consonant. However, shortening due to destressing involves global reduction of the *opening gesture* for the vowel, evident from the beginning of the gesture. The similarity between these findings and those on English suggests a fundamental similarity in this aspect of their timing profiles.

1. INTRODUCTION

The global aim of the research of which this paper reports part is to explore the processes governing the sequencing of consonants and vowels in languages such as Italian and English, traditionally identified as *syllable-* vs *stress-timed* .

The present paper will focus on the timing of vowels and consonants in Italian. The phenomena we examined belong to the class of so called *compensatory shortenings.*

The term "compensatory shortening" (henceforth CS; see [12]) refers to a variety of shortening phenomena, in speech. They have in common that the increases in duration of a speech unit due to one source are *partially* offset by shortening elsewhere, in that unit (for a review, see [6], [7]).

According to one interpretation these shortening patterns reflect a "real" effort to compress the duration of a speech unit (a vowel or a syllable) to maintain a regular duration for the higher level unit as a whole (syllable or foot/word). As such they might be symptomatic of a tendency that languages are said to exhibit to maintain isochrony of certain units of speech [12].

However, many doubts have been raised about the compensatory nature of these patterns. They might be the acoustic, epiphenomenal effects of vowel-consonant coarticulatory overlapping: overlapping of a vowel by neighboring consonants, and of a stressed vowel by the following unstressed vowels, within a foot (at least in so called stressed-timed languages).

Following Öhman [17], Fowler suggests that, where possible, vowel production is cyclic during speech, that is vocalic gestures are sequential and adjacent, with consonants somehow superimposed on them, as more local, individual events. (see, e.g., [5], [7], [9], [19]).

From this perspective, "vowels constitute a somewhat separate articulatory stream from gestures involved in consonant production" ([7] p. 393). Consequently, they should bear the major responsibility for preserving the serial order of consonants and vowels involved in a planned sequence.

As far as syllable-level CS is concerned, this interpretation seems to be supported by the acoustic and articulatory data reported for English by Munhall *et al.* [15], in which vowel shortening with added consonants is examined. Munhall and collegues found no evidence of (articulatory) shortening of the vowel opening gesture when one or more consonants were added to the syllable coda. The jaw lowering gesture for the vowel had about the same duration and extent regardless of the length of the coda. Instead, Munhall et al. report an earlier onset of the jaw raising gesture for the consonants in coda position.

However, as Munhall *et al.* observe, the acoustic shortening of a vowel may have several different articulatory origins, reflecting changes in the programming of individual movements, rather than coarticulatory overlap. For example, unstressed vowels are produced by movements that have lower peak velocities, are shorter in duration and have smaller amplitudes than their stressed counterparts .

Compatibly with this scenario, our previous work on Italian [22, 23] shows both acoustic (duration, F0, amplitude, F1) and articulatory (jaw displacement) evidence that, in Italian as in English, a (low) unstressed vowel is shorter in duration compared to its stressed counterpart and exhibits reduction in the height dimension, involving the global gesture for the vowel.

In the present experiment we examine i) the acoustic shortening of a vowel before tautosyllabic as compared to heterosyllabic consonants ("Closed Syllable Vowel Shortening", [13]); ii) the acoustic shortening of a stressed vowel before unstressed syllables, within a foot. We ask whether in Italian as in English syllable-level shortening is apparent and reflects "a greater coarticulatory encroachment on the vowel by a cluster than by a singleton consonant" [15].

As for Italian timing typology, evidence favoring its classification as syllable-timed is equivocal ([20], for a review). Previous studies [4, 21, 14] report weak shortening of stressed vowels by following syllables within a word or foot: although certainly weaker than in English, nevertheless this type of shortening is statistically significant [21, 1]. Unlike English, however, the direction of vowel shortening ("anticipatory" *vs.* "backward") in Italian is not uniform across subjects, nor is the direction of coarticulatory influences of stressed vowels on unstressed vowels ("carry-over" vs. "anticipatory": see [24]). In conclusion, in spite of the proposal that a left dominant foot structure explains word-level patterns of relative prominence in Italian [16], the existing phonetic literature provides no evidence

that the foot serves as an effective organizational constituent in the production of Italian words (see [2] for criticism of the role of this unit in Italian phonology). To verify this state-of-affairs, our present study asks: i) whether we can replicate evidence of any, even weak, shortening of a stressed vowel as a function of the number of following unstressed syllables in a word; ii) whether opening-closing patterns associated with V-C sequences in foot-level compensatory shortening contexts are similar (when such shortening is present) to gestural patterns characterizing V-C sequences in syllable-level "compensatory shortening" contexts.

As a source of information about the opening-closing gestures involved in V-C coordination the experiment examines vowel durations and F1 trajectories of stressed /a/ in syllable- vs. word-level shortening contexts. In addition, we compare these patterns in stressed and unstressed /a/.

2. METHOD

2.1. Corpus. We compared acoustic measures of the vowel /a/ in word-initial syllables, according to our three shortening contexts: i) /'Ca.CV/ *vs.* /Ca'.CV/; ii) /'Ca.CV/ or /'Ca.CCV/ *vs.* /'CaC.CV/; iii) /'Ca(C).CV/ *vs.* /'Ca(C).CV.CV/.

The word-initial consonant was /t/; intevocalic singleton consonants were: /p, m, t/; intervocalic CC sequences were: geminates (/pp, mm, tt/) or clusters. The latter were heterosyllabic (/pt, mp/) or tautosyllabic (/pl/). We devised 17 pseudo-words (closely resembling natural ones, such as: /'tappa/≈"cappa" or /'tapta/≈"capta") that were produced 4 times by three subjects in a carrier sentence.

2.2. Measures. The data we report in the present paper are: vowel durations and trajectories of F1. The productions of all the subjects (MN, AA, SS) have contributed to the analysis of durations; however, only the data from MN and AA have been measured and used in the analysis of F1.

Formant values were obtained from a series of pitch-synchronous spectra based on a narrow band FFT. We compared F1 trajectories in the different shortening contexts adopting the following procedure: for each subject and repetition, we first plotted pairs of F1 trajectories for /a/ in each shortening context and for each consonant type. For example, we paired /'tapa/ with /'tappa/, /'tapta/, /'tapla/; and /'tama/ with /'tamma/, /'tampa/ to explore syllable-level compensatory shortening. We paired /'tapa/ with /'tapala/, /'tappa/ with /'tappala/ etc. to explore word-level compensatory shortening. For each comparison, in the F1 trajectory of the acoustically shorter vowel, we selected a point that corresponds to the probable beginning of the closing gesture for the following consonant. In Figure 3, the key-point is marked with an arrow in the trajectory of the /a/ of /'tapa/. We then selected the corresponding point in the F1 trajectory of the longer vowel (the /a/ of /'tappa/). The two sections of paired trajectories were smoothed by taking a 3-point moving average and were averaged across subjects. Finally, analyses of variance were performed on each paired trajectory from the beginning of the vowel to the key-point.

3 RESULTS

To examine syllable and word structure effects on vowels, we compared duration and F1 trajectories of stressed /a/ in the two following contexts: i) open *vs.* closed syllables in bisyllables: /'tapa, 'tapla, 'tata, 'tama/ *vs.* /'tappa, 'tapta, 'tatta, 'tamma, 'tampa/; ii) bisyllables *vs.* trisyllables: /'tapa/, etc. *vs.* /'tapala, 'taplala, 'tamala, 'tappala, 'taptala, 'tammala/. As for the effect of stress, we examined the same acoustic measures of stressed and unstressed /a/, in word initial syllable of bisyllables /'tata/ *vs.* /ta'ta/.

3.1. Durations. We first ascertained that all three speakers produced longer tokens of /a/ in stressed than in unstressed syllables; in open than in closed (stressed) syllables; in stressed syllables followed by one vs. two unstressed syllables in a word.

3.1.1. Stress effect. A two-way analysis of variance with factors "stress" and "talker" was performed on the durations of stressed and unstressed word initial /a/. The average values showed a ratio of 1:2.5 (unstressed: 70.75 ms; stressed: 178.53 ms). As expected, we found highly significant effects of stress for the three talkers as a group ($F(1,18)= 422.00$; $p=.0001$). The effects are also highly significant for each individual talker (and the interaction between "talker" and "stress" is non significant).

3.1.2. Syllable-level compensatory shortening. Figure 1 shows, for the three subjects, the combined effects of "syllable type" (open, closed) and following "consonant type" on stressed /a/ in bisyllabic words: where consonants are singletons and geminates /p, m, t/ and clusters /pl, pt, mp/.

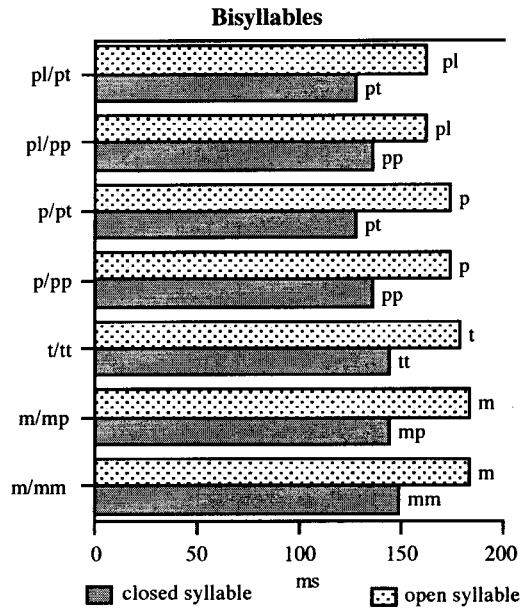

Figure 1. Mean duration (ms) of stressed /a/ as a function of syllable structure and following consonant (labial *vs.* nasal *vs.* coronal).

A three-way analysis of variance with factors "syllable type", "consonant type" (singleton and geminate /p, m, t/) and "talker" was performed on the duration values of stressed /a/ in bisyllables. In accordance with Maddieson's [13] proposal of a process of "Closed Syllable Vowel Shortening" as a universal phonetic tendency, we found a highly significant effect of syllable type ($F(1,54) = 106.136$; $p =.0001$).

Compatibly with the general phonetic tendency for vowels to shorten more before labial than before coronal (or dorsal) consonants [10], and before voiceless than voiced consonants [3], we found a significant effect of consonant type: the vowel's duration was significantly shorter for all the subjects before /p/ than /t/, and before /t/ than /m/ (F (2, 54)=4.25; p =.019).

A two-way ANOVA, with factors "cluster type" (/pl, pp, pt, mp/) and "talker" shows a highly significant effect of cluster type (F (3,36)=23.905; p =.0001), and "talker" (F(2,36)=6.50, p=.004) on vowel duration. Mean duration of speaker SS's vowels were globally longer.

Post-hoc Student-Neuman-Keuls tests showed that, for the three subjects, vowel durations were significantly longer before /pl/ than before /mp/, /pp/ and pt/, and before /mp/ than /pp/ and /pt./.

Moreover, /pp/ and /pt/ exhibit the strongest shortening effect, while the longer duration of /a/ before /pp/ than /pt/ is not statistically significant. As might be expected, the geminate /pp/ and the cluster /pt/ had a similar closing effect on vowel duration.

Unexpectedly, the phonetic behavior of the obstruent+liquid cluster /pl/ (supposedly a tautosyllabic cluster, from the phonological point of view) was somewhat ambiguous in terms of syllable affiliation. On one hand, it patterned as a heterosyllabic cluster, so that its shortening effect appeared significantly weaker than that of other clusters (and geminates). However, the outcome of a two-way ANOVA with factors "consonant type" (/p/, /pl/) and talker, showed that the /pl/ shortening effect on vowel duration was significantly greater than that of the heterosyllabic singleton /p/ in /tapa/ (F (1,18) = 6.28 p =.022).

3.1.3. Word-level compensatory shortening. Table 1 compares mean durations (three subjects, all consonant types) of stressed /a/ in open vs. closed syllables, and in bisyllables *vs.*trisyllables.

	BISYLLABLES	TRISYLLABLES
OPEN	174.2	155.4
CLOSED	139.7	131.2

Table1. Mean duration (ms) of stressed /a/ in bi- and trisyllables across syllable type.

Alhough weaker than vowel shortening in closed syllables, the shortening of stressed vowels as a function of following unstressed syllables within a word is evident. A three-way ANOVA with factors "word structure" (bisyllables, trisyllables), "syllable type" (open, closed) and "talker" was performed on stressed vowel durations in a subset of words, with target vowel followed by singleton or geminate /p/ and /m/. Word structure effects were highly significant (F(1,84)=24.168; p=.0001) and uniform across subjects: the interaction of word structure with talker was nonsignificant. The factor "talker" was significant (F(2,84)= 7.306; p =.0012). A separate ANOVA on trisyllables only, with singleton vs. geminates /p/ and /m/, showed that SS, the subject generally having the longest durations, had significantly longer /a/ than MN in trisyllable productions.

3.2. First formant trajectories.

3.2.1. Stress effect. Figure 2 compares F1 trajectories of two tokens of stressed and unstressed /a/ produced by subject AA. This type of comparison reveals that the *oral opening* gestures for the vowel in stressed vs. unstressed position diverge *globally* from the beginning. Two separate one-way analyses of variance (levels: stressed vs. unstressed vowels) were performed on the trajectories' values for the two talkers. In accordance with the strong acoustic shortening found in unstressed position, we found for both subjects a highly significant effect of stress on F1, such that stressed /a/ is a more open vowel than is unstressed /a/ (MN: F(1,6)=45.22; p= .0005; AA: F (1,4)= 117.97; p = .0004).

Thus, consistently with what we and others have previously observed [18], and with a general tendency across the world's languages to reduce in unstressed position [13], we find that in Italian unstressed (low) vowels are subject to phonetic reduction (at least in the height dimension). Reduction, a feature often attributed to stressed-timed languages, therefore plays a role in the phonetics of Italian stress.

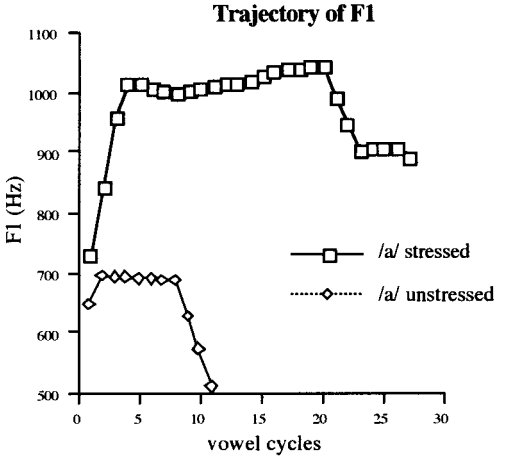

Figure 2. Smoothed F1 trajectories for stressed *vs.* unstressed /a/ in word-initial syllable. Subject AA, 4th repetition.

3.2.2. Syllable structure effect. The pattern of F1 trajectories was remarkably different when vowel shortening was due to syllable structure (open vs. closed) instead of presence *vs.* absence of stress.

Figure 3 shows formant trajectories of two tokens of stressed /a/ in open *vs.* closed syllables, produced by subject MN. Two separate sets of one-way analyses of variance (levels: open *vs.* closed) were performed for the two talkers on F1 values of the common parts of the formant trajectories, in pairs of comparable bisyllabic words (ex., /'tapa, 'tappa/; /'tapa, 'tampa/; /'tapa, 'tapla/, etc.). Neither of the subjects showed significant effects of syllable structure on this part of the trajectory, with the exception of one pair produced by MN (/'tapla, 'tapta/: F (1,6) = 7.32; p= .035).

Figure 3 suggests how the acoustic shortening of a vowel before a tautosyllabic consonant might be accomplished. In accordance with Munhall *et al.*'s proposal, the stressed vowel's acoustic shortening in /'tappa/ as compared to /'tapa/ seems to be determined by an earlier onset of the *closing gesture* associated with the consonantal coda, and not by a reduction of the opening gesture, as it is for an open unstressed vowel. The anticipation of the raising gesture caused truncation of the lowering movement associated with the vowel. Under the hypothesis of vowel-consonant coproduction, we may have a case of *articulatory*

blending of two oral gestures competing for an interval of time on the use of a common articulator (the jaw).

3.2.3. Word structure effect. To establish whether the weak (but significant) word-level shortening of a vowel has a similar articulatory origin to that characterizing vowel shortening in closed syllable contexts, two separate sets of one-way analyses of variance (levels: bisyllable vs. trisyllable) were performed for the two talkers on the common part of the formant trajectories (here we examined pairs such as, e.g.,. /'tapa, 'tapala/; /'tama, 'tamala/; /tappa, tappala/, etc.). Even in this shortening context, the behavior of the two subjects is uniform. MN does not show any significant effect of word structure on the opening gesture for the vowel, while in AA's productions we found significant differences associated with the opening gesture in only one pair: /'tampa, 'tampala/ ($F(1,2)= 361.54$; $p= .002$).

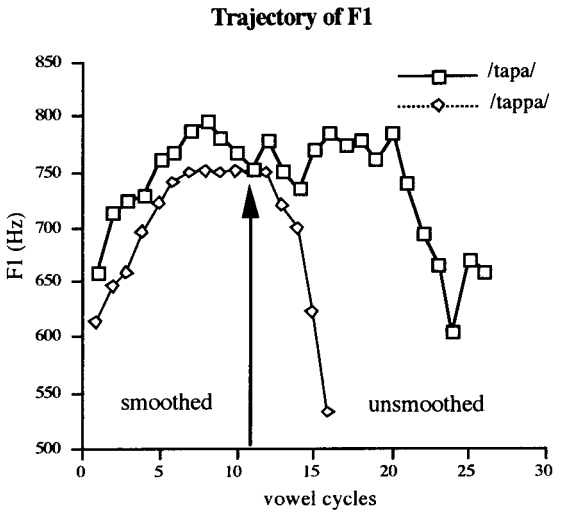

Figure 3. F1 trajectory of vowel /a/ in open *vs.* closed syllable (subject MN, 4th repetition). The arrow indicates the "key-point", i.e. the beginning of the closing gesture for the shorter vowel in this pair.

4. CONCLUSION

The results suggest that a phonetic definition of linguistic units such as the syllable, often considered elusive to experimental observation, is possible. Examining V-C sequences, we found that, in Italian, F1 trajectory patterns of a vowel in open *vs.* closed syllables may offer, together with the vowel's durational shortening ([13]), reliable phonetic information for the syllabic affiliation of the following consonant.

We explained the vowel's acoustic shortening in this context as due to the overlap of consonants and vowels; this produces *blending* of successive movements that share a common articulator. Thus, in closed syllable contexts, an earlier onset of the closing gesture for the consonant than in open syllable contexts "truncates" the vowel by overlapping with the opening gesture for the vowel.

Unexpectedly for a language often described as syllable-timed, we also found evidence in Italian of significant shortening of a stressed vowel as a function of the number of following unstressed syllables, within a word or foot. The same V-C overlapping strategy appeared to be at work here as in closed syllable shortening.

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