

HYPOSPEECH, VOWEL REDUCTION, CENTRALIZATION: HOW DO THEY INTERACT IN DIAPHASIC VARIATIONS?

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Aim of our work is to stress the differences between two different forms of vowel reduction: a) phenomena due to hypoarticulation that cannot easily be added to a general description of vowel systems and b) centralization which is related to prosodic conditions (presence/absence of stress) and then to phonological factors that can be predicted. We performed a comparative spectroacoustical analysis of vowel reduction phenomena in two different speech styles, one more accurate and partially read and another one absolutely spontaneous, presenting all the typical features of 'hypospeech' as defined by Lindblom (1990). We conclude that, while reduction phenomena related to hypoarticulation are incremented in less accurate speech styles, centralization is a structural feature not depending on diaphasic as well as on diatopic variation.

Keywords: vowel reduction, hypoarticulation, centralization, diaphasic variations, diatopic variations.

1. INTRODUCTION

Italian, like many other languages, presents vowel reduction phenomena. Whereas some studies confute this hypothesis (Bertinetto, 1981) more recent papers support it (Vayra, 1989; Albano Leoni *et al.*, 1995a; Albano Leoni *et al.*, 1995b; Giannini and Pettorino, 1992), although terms such as "vowel reduction" or "vowel centralization" are used without any distinction. We claim, on the other hand, that two types of reduction ought to be distinguished:

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1) the timbre reduction due to *hypoarticulation*, strictly related to the level of the articulatory accuracy, i.e. to the speaking style considered;

2) the reduction due to the interaction between stress and vowel production, i.e. related to unstressed positions, which we will refere to as *structural centralization*.

The *Hypoarticulation* phenomenon is a general one: it affects the whole segmental structure of speech. In connected speech production most of the articulatory target positions are not reached, consequently acoustic parameters corresponding to the gestures appear to be significantly different from the ones observed in the formal production. In this view, the term hypoarticulation is used to define a class of reduction phenomena. The theoretical framework within which this phenomenon finds its best description is the 'target undershoot' model (Lindblom and Studdert-Kennedy, 1967; van Son, 1993; van Bergem, 1995).

Centralization, as we view it, is a form of timbrical reduction determined only by stress variables (van Bergem, 1995). Unstressed vowels tend to be produced in a more central articulatory position than stressed ones; from a spectroacoustic point of view this results in a shift of F_1 and F_2 values. These two phenomena, differing in their origins, may actually combine their effects: in more accurate speaking styles we find centralization, with a small presence of hypoarticulation; in more informal and less accurate styles, hypospeech adds its large-scale effects to the ones due to structural centralization.

This work aims to describing the main characteristics of both phenomena and to show how they act together in the informal diaphasic variety.

2. METHODS

2.1 Corpora

Our work is based on spectroacoustical analyses of two corpora of vowels segmented from Italian connected speech. The first corpus (**Formal Speech**) consists in speech utterances produced by readers of regional TV-news bulletins (Albano Leoni *et al.*,1995a; 1995b). It is representative of a speech style partially read and quite accurate; the FS corpus consists of 3200 vowel sounds extracted from speech utterances produced by 20 female speakers belonging to four different italian regions (Lombardia, Toscana, Lazio, Campania). The second corpus (**Informal Speech**) derives from recordings of face-to-face conversations, captured with hidden microphone. This material is part of a wider corpus used for the creation of LIP (De Mauro *et al.*, 1993), a lexicon of spoken Italian. The speech material in this corpus is completely spontaneous and it is characterized by the presence of all the typical features of hypospeech (Lindblom, 1983; 1990). The IS corpus consists of 320 vowel sounds produced by 2 female speakers coming from Campania. According to Italian vowel phonology, we divided the data coming from both corpora into various categories thus obtaining three vowel systems: stressed (7 vowel categories belong to this system in Italian: i, e, ɛ, a, ɔ, o, u), non-final unstressed (5: i, e, a, o, u) and word final unstressed vowel system (4: i, e, a, o). We took 10 item for each of the above vowel category. We chose only vowels extracted from content words. Vowels were always preceded and followed by consonants, word-final vowels were selected only if first sound of following word was a consonant.

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2.2 Phonetic analysis

We measured values of first and second formant (F_1 and F_2) in the average power spectrum of the medial portion of each considered vowel sound. Data are represented on an F_2/F_1 plane with scale-inverted axes. Vowel systems will be graphically rendered as a set of ellipses with centre coordinates corresponding to the average values of F_1 and F_2 for that category, and axes proportional to the value of respective standard deviations. For both corpora we calculated the 'centroid' (Koopmans-van Beinum, 1983) of the stressed vowel systems. We used this ideal point as a reference in order to evaluate geometrical distances between the three vowel systems. We used the centroid calculated in the stressed vowels system as a reference point for the evaluation of areas displacements in non-final unstressed and final unstressed ones. For each vowel category we compared distances between the centre of ellipses in each system and this point, obtaining in this way a direct quantification of the processes involved in the passage through the various stress conditions.

3. RESULTS

3.1. Centralization

In the analysis of the FS corpus, we observed a gradual phenomenon of timbrical vowel reduction in the passage from the stressed vowel system to the unstressed one. A spectroacoustical correlate of centralization is the sliding of formant values toward a central portion of the F_1/F_2 plane.

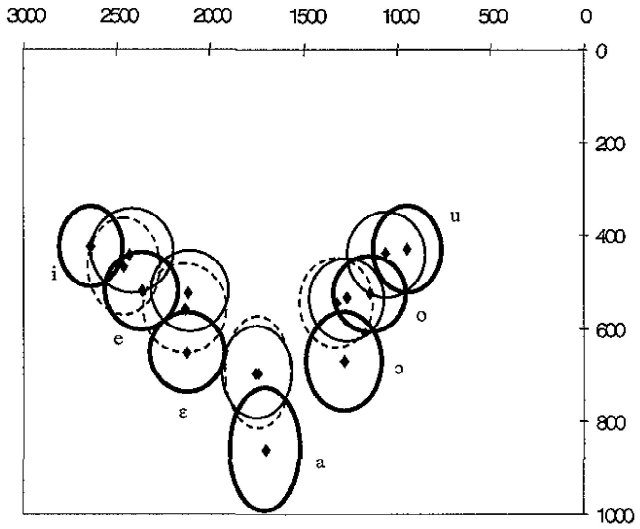

Fig. 1. Vowel systems in FS corpus. Thick lines: stressed vowels. Thin lines: non-final unstressed vowels. Dotted lines: word-final unstressed vowels. (X-axis F_2, scale-inverted, in Hz, Y-axis F_1, scale-inverted, in Hz)

The calculus of centroid coordinates for the stressed vowel systems gives following values:

$$F_1 = 581 \text{ Hz} \qquad F_2 = 1742 \text{ Hz}$$

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In order to quantify the degree of this sliding we calculated geometric distances between each ellipse drawn in Fig. 1 and this centroid, (Table 1).

Table 1 Geometric distances between ellipses' centres of the three vowel systems and centroid of the stressed one (FS corpus).

	i	e	ɛ	a	ɔ	o	u
stressed	912	624	389	281	469	598	812
non-final unstressed	703	377		119		475	700
word-final unstressed	728	392		117		422	

A systematic shortening of this distance can be noticed in the passage from the stressed system to the unstressed ones. Many authors identify the portion of the plane toward which all the ellipses converge to as related to the *schwa*. In the light of these results this statements seem to be too reductive. It is our opinion, according to van Bergem (1995), that this phenomenon comprises a wider class of central vowels.

Furthermore, comparing the distances expressed in the two last lines in Table 1, one can also observe that final and non-final unstressed vowel systems appear to be quite similar in the FS corpus.

Some consideration can be thus drawn from our data:

1) centralization is a structural phenomenon. It is mainly related to prosodic variables (presence/absence of stress), therefore it can be partially predicted;

2) it is independent from diatopic variations: analyses of samples of different regional provenience (Savy and Cutugno, 1997) show that, despite differences among various vowel systems, a centralization process is present with similar evidence in all groups; we will not go into deeper details about this argument in this paper;

It is now our intention to show another feature of centralization, perhaps the most important one: we want show that it is independent from diaphasic variations, that is to say that mutual internal relations among stressed and unstressed vowel systems are preserved through different speech styles.

3.2. Hypoarticulation

In order to verify this last statement we performed a comparative analysis of vowel reduction phenomena between the two corpora differing in the diaphasic dimension. We then applied to IS corpus the same kind of phonetic analysis already applied to FS corpus. Similarly to what we have already shown for the FS corpus, in the IF corpus slight shifts in the values of F_1 and F_2 toward the central portion of the plane F_1/F_2 for unstressed final and non-final vowels are observable in Fig. 2. On the other hand, differences in the internal structure, in the relative

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positions and in the shape of the areas assigned to each vowel category are observed in each

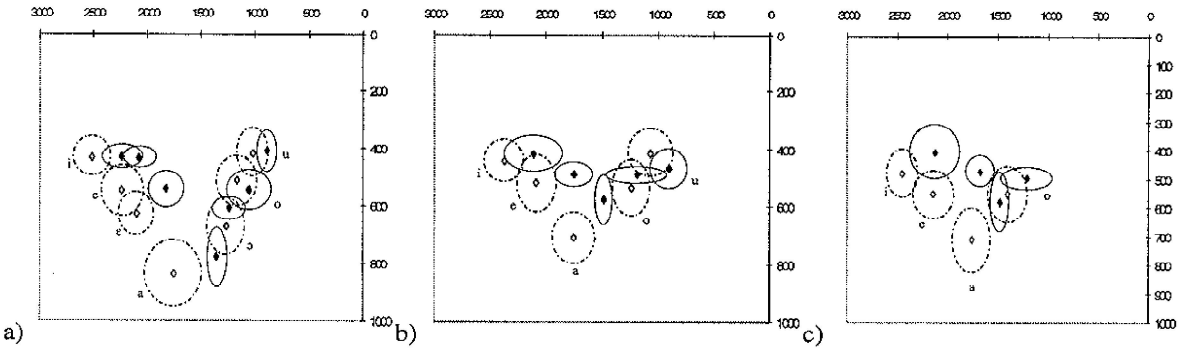

Fig. 2 A comparison between IS and FS vowel systems. a) stressed vowels; b) non-final unstressed; c) word-final unstressed. For all graphs: solid lines:IS corpus, dotted lines:FS corpus; (X-axis F_2, scale-inverted, in Hz, Y-axis F_1, scale-inverted, in Hz)

system.

We calculated centroid coordinates for stressed vowels in IS, resulting values are:

$$F_1 = 537 \qquad F_2 = 1525$$

Also for IS corpus geometrical distances from stressed vowel centroid for the three system were calculated, Table 2.

Table 2 Geometric distances between ellipses' centres of the three vowel systems and centroid of the stressed one (IS corpus).

	i	e	ɛ	a	ɔ	o	u
stressed	717	558	297	294	292	467	649
non-final unstressed	594	229		58		343	629
word-final unstressed	608	158		67		317	

In IS the vowel system is realised with the following main features:

1) a general sliding of the whole front vowel set, i.e. of /i/, /e/, /ɛ/ and including /a/, toward a retracted articulation;

2) reduction in the range of variability of F_1, both for the system considered as a whole and

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for physical realisations within each vowel category, (this happens mainly in the unstressed final and non-final systems, except for vowel /a/);

3) frequent overlaps of phonic existence areas, mainly in the unstressed final systems for which all the areas tend to converge toward a central portion of the F_1/F_2 plane. In this case, differently from what observed in the previous section on the FS corpus, the vowel reduction take the form of a neutral vowel: in our data both the portion of the plane toward which all the ellipses converge and F_1 ed F_2 values for IS centroid are coherent with the values that a schwa would assume.

3.3. Dynamic analysis of utterances

The dynamic analysis of an hypoarticulated (IS corpus) speech utterance is shown in Fig. 3. In the picture F_1 and F_2 patterns are presented in parallel with f_0 movements. The utterance is composed by three tone-units (TU). In the picture they are individuated by means of solid lines in the f_0 pattern window. In each TU main accents are marked by dotted lines involving both formant and pitch patterns. As can be clearly seen F_1 excursions occur within a short interval centred around the value of 500 Hz with 200 Hz of width (380÷650 Hz). F_2 excursions are limited too (1300÷2400 Hz), although this reduction has a smaller proportion. Reasoning in articulatory terms, these data suggest us that, in this speech style, jaw and tongue, due to the necessity of performing their movements at a fast rate, are forced to restrict the size of their excursions both on the vertical (openness) plane and, but less, on the horizontal (frontness) plane. At the same time, the observation of intonational contours shows that the quality of nuclear vowels carrying a pitch accent, despite of the limited range of variation of formant values, is clearly marked if compared to the one of other vowels.

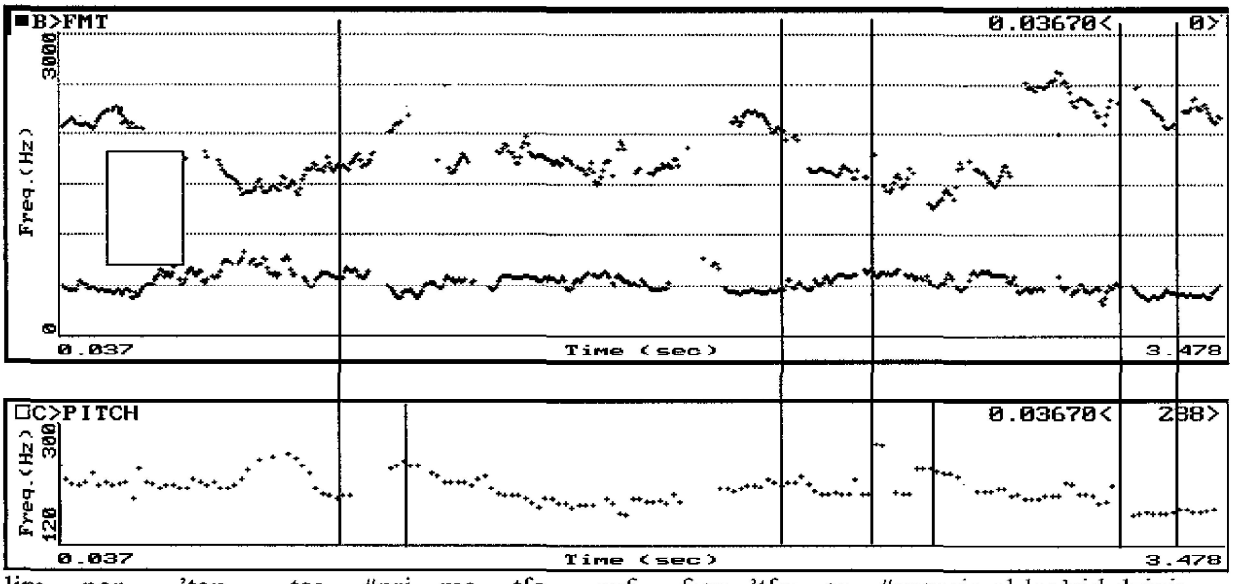

Fig.3: f_0, F_1 and F_2 patterns for the Italian sentence «[...]*l'importanza # prima c'era il francese# proprio alle origini*[...]» ([...]the importance # before there was French# just at the origins[...])(IS corpus). Vertical solid lines in the f_0 frame mark the tone-units boundaries, longer dotted line, extending along both frames, aim to align nuclear

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accents within each TU with the corresponding stressed vowel.

4. DISCUSSION

Co-variance of intonational and segmental phenomena seems to constitute a sort of phonctic invariant in various speaking styles: stressed syllables control the reduction, permitting the *maintenance of an optimal distinctiveness of timbrical quality also when hypoarticulation is* present; absence of stress indexes seems to favour the reduction processes. Looking at the internal structure of the vowel system (both FS and IS), effects of these processes create clear differences between stressed and unstressed subsystems: this difference doesn't seem to depend on the used speaking style and on the degree of accuracy, but it can be regarded as a structural phenomenon (centralization). The comparison of vowel systems in different speaking styles shows that the lesser the degree of accuracy in the articulation of speech sounds the higher the presence of reduction (hypoarticulation). This process is influenced by a complex set of factors and hence it is not easily foreseeable neither in its amount nor in its direction. The most relevant consequences of the last process are:

1) limitation in the articulatory excursion mainly along the openness axis for the produced vowels;

2) frequent realization of reduced vowels including the neutral vowel schwa.

Previous considerations can be simply resumed using the standard IPA articulatory scheme for vowels reported in Fig. 4. We should notice that all vowel sounds produced in any condition of deaccentation (including into this category also lexically stressed vowels not involved in the production of a pitch accent) are approximately pronounced using articulatory positions falling into the shaded area of the graph.

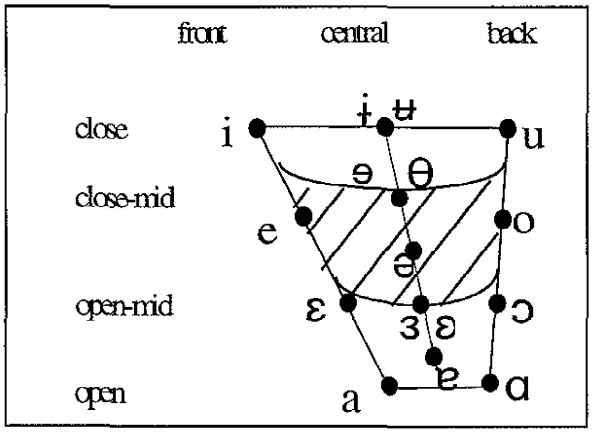

Fig. 4 IPA articulatory chart for vowels. The shaded area indicates position preferred in the production of deaccented vowels.

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[i] This work derives from the continous collaboration of both authors. RS materially wrote sections 1, 3.1, 3.2, 4; FC wrote sections 2, 3.3.

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