ACOUSTIC CORRELATES OF LINGUISTIC BOUNDARIES IN ITALIAN:
A STUDY ON DURATION AND FUNDAMENTAL FREQUENCY

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ABSTRACT
The paper concerns the acoustic realization of some selected boundary types in Italian. Scope of the paper is to investigate whether the concept of boundary magnitude is applicable to Italian and to study the relationship between duration and F0 as boundary signals. The data on three subjects indicate that within-phrase boundaries are usually not signalled, while for between-phrase and between-clause boundaries both the temporal pattern (the duration of the temporal interval between onset of the domain-final syllable and onset of the domain-initial syllable) and the type of the F0 contour are clear indexes of the degree of cohesion/separation between the units. The present data seem to suggest a priority of the function of F0 as a boundary signal over its function as a stress correlate.

INTRODUCTION
The present paper reports some preliminary data on the acoustic manifestation of boundaries in Italian. The variables analyzed are temporal structure and fundamental frequency. The test boundaries are located: between words within an NP, between an NP and a VP, between an NP and a subordinate, adjacent clause and between two main clauses. One goal of the study is to verify the validity of the principle of boundary magnitude [1], which constitutes an important point of evidence in support to a hierarchical view of the prosodic structure. Experimental data on the production and/or the perception of boundaries, [1,2] indicate that the units of performance, i.e. the units in which speakers divide the speech stream and listeners perceive as such, tend to reflect the hierarchy of the surface syntactic structure, although other factors can affect the structuring of speech into units [1,2]. A second goal is to determine the relative contribution of the temporal structure and the intonation contour to the makeup of the different boundary types. Perceptual experiments on English [1] indicate that boundary assignments correlate with durational variations but not with F0 parameters. On the other hand, production studies on German [3] and on Swedish [4] suggest that F0 is as systematic as the temporal structure in signalling the degree of cohesion among the speech units. One hypothesis on the relationship between duration and F0 is that the relative contribution of the two parameters to signal the boundaries may depend on their interplay in accomplishing other functions, for instance in signalling prominence relations. Presumably, as suggested by Vaissière [5], interlanguage differences lie in the different relationships among parameters i.e. in the priority of different acoustic features in the accomplishment of the same linguistic functions in different languages. Following this line of reasoning, in Italian F0 may be expected to have an important role as a boundary signal, since duration has proved to be the most systematic correlate of stress [6].

METHOD
The corpus consists of five pairs of utterances. The utterances a) and b) of each pair have same accentual pattern, same number of syllables, same boundary type and differ for the location of the boundary, which occur after a bisyllable in a) and after a trisyllable in b). The boundaries are: 1) word boundaries, W,M, located within sentence-initial and sentence-final NPs (key sequences: "la nana natale. . .. vs "...la nanana tale."); 2) phrase boundaries, NP/VP, ("La nana nasconde." vs "La nanana scossa."); 3) boundaries between NP and a subordinate clause, NP/Cl, ("La nana, nascosta. . .; 4) boundaries between sentences, S/S, ("...la nana. Nascosta. . . vs ". . .la nanana. Scossa."). The corpus was read six times with neutral intonation by three subjects, two males (S1, S3) and a female (S2), S1 from Tuscany, S2 and S3 from Northern Italy. Four segments were analyzed: the syllables /'na na na/ and onset and nucleus of the following stressed syllable. We measured the durations of the test segments and of
the silent intervals at the boundary locations; the values of F0 at the boundary locations and at the points of F0 maxima and minima. Within-pair comparisons made it possible to determine whether or not a boundary is realized, cross-pair comparisons evaluated the relative magnitude of the boundaries.

RESULTS AND COMMENTS

Segmental Durations. The durations of the second and of the third test segments /na na/ of each utterances were the dependent variable of a set of ANOVAs, where the factors were: position of the segment (2nd vs 3rd), boundary condition (final vs non-final) and boundary type. The data indicate that there are no effects of word boundaries nor effects due to the position of the phrase in the sentence. The mean durations range from 100 to 126 ms for S1, 104 to 111 ms for S2, 107 to 124 ms for S3. The NP/VP boundaries seem to be realized systematically only by S3, with final syllables significantly longer than non-final (post-hoc Newman-Keul test, p<0.01); this speaker tends also to lengthen the domain-initial syllables (mean values: 145, 114 and 102 ms for final, initial and medial syllables, respectively). For S1 and S2 there are durational differences in the expected direction but they do not reach significance. As for the NP/Cl and the S/S boundaries, the domain-final syllables are significantly longer than the non-final syllables for all the subjects (mean values for NP/Cl boundaries: 175 vs 122 ms (S1), 153 vs 111 ms (S2), 145 vs 109 ms (S3); for S/S boundaries: 140 vs 121 ms (S1), 154 vs 113 ms (S2) and 146 vs 114 ms (S3). It can be seen that increase in boundary magnitude in terms of final lengthening occurs from NP/VP to NP/Cl but not from NP/Cl to S/S. Fig.1 shows the mean durations of the four test segments, averaged across the three subjects. For each boundary type there are two durational patterns, one referring to the a) utterances, the other to the b) utterances of each pair. The more the patterns coincide, the weaker is the boundary. It can be observed that there is no increase in boundary magnitude from VP/Cl to S/S.

Pauses. The durations of the silent intervals between the offsets of final syllables and the onsets of the following initial syllables contribute in an important way to distinguish the different boundary types. As for their frequency, no pauses were observed at word boundaries and very few were found between NP and VP (see Fig.2). Those between NP and Cl occur 100% of the times for S3 and around 70% for S1 and S2, and their mean durations tend to be shorter than those between sentences, which reach the 100% of occurrence for all the subjects. The data clearly indicate that the silent intervals are complementary to final lengthenings in signalling the magnitude of the boundaries. Thus, what seems to be a good

![Figure 1](image-url)
Fig. 2. Durations and frequency of occurrence of pauses at boundaries; circles: NP/VP, triangles: NP/Cl, squares: S/S.

Fig. 3. Durations of the temporal intervals between onsets of domain-final and domain-initial syllables for various boundary types.

The index of boundary magnitude is the sum of final lengthening and pause duration, i.e. the temporal interval between the onset of the domain-final syllable and the onset of the domain-initial syllable, as clearly illustrated in Fig.3. The figure shows that the mean duration of this interval increases gradually from W/W to S/S for all the subjects.

Fundamental frequency. Fig.4 shows the fundamental frequency data for S2. The stylized contours refer to the sequence of the four key segments. For each boundary type the continuous and the broken lines connecting the points refer to the a) and to the b) utterances respectively. The stylized contours were constructed by identifying the direction of F0 movements, the points of maxima and minima, the F0 values at the onset of the first syllable, at the offset of syll.2, of syll.3, and at the end of the last vowel of the sequence. The points are aligned along the time axis with the onset of syll.1 as origin. The temporal axis is constructed on the syllable durations, excluding the pauses. For each boundary type the comparison of pattern a) - bisyllables - with pattern b) - trisyllables - indicates whether or not the boundary has been signalled. When boundaries are not signalled, the two patterns coincide on the temporal axis, hence the boundary loci (2 and 3 marked by arrows) have different F0 values. When the boundaries are signalled, the two patterns do not coincide and the boundary loci tend to have the same values. The figure shows that all the boundaries are signalled by F0 except the W/W boundaries for which it can be seen that the word boundaries occur at different points of the F0 trajectory, indicating that the F0 contour is related to other functions and is not affected by this boundary type. The NP/VP and the NP/Cl boundaries are realized through a rising movement that starts at the same point in time for bisyllables and trisyllables and reaches its peak at the end of the unit, the S/S boundaries are realized by means of a falling movement which reaches its lowest point at the end of the unit. For this subject the F0 slope is steeper for bisyllables than for trisyllables. Globally the F0 contours for the S1 and S3 are very similar to those just described and indicate that F0 is as systematic as the temporal structure in signalling the boundaries, moreover, since all three subjects realize the NP/VP boundary by means of F0, it is possible that F0 has a priority over duration in signalling boundaries between units with a rather strong syntactic/semantic relation like NP/VP.

In this sense F0 function can be considered to be complementary to duration for weaker boundaries and additive to temporal structure for stronger ones. The data also suggest that for the present utterences produced with neutral intonation the relationship between F0 and prominence is less direct than the relationship between duration and prominence. The peaks and the dips of F0 occur in coincidence or nearby the stressed syllables in a systematic way only for the stressed syllables of the phrase-non-final words, that is, when the word boundary is not signalled. In all the other cases, where F0 is involved in the realization of the boundary, the starting
point of the F0 movement (be it a rise or a fall) preferred by S2 and S1 is the stressed syllable; in this sense F0 can also signal the locus of prominence. However this pattern is not systematic in these two subjects and does not characterize the production of S3, whose starting point can occur well before the stressed syllable and is probably related to the size of the word: in these cases the stressed syllable is located along the F0 trajectory towards the peak or the dip together with the unstressed syllables and only duration can signal the presence of stress.

Our hypothesis on how duration and F0 may interplay in Italian as prominence/boundary signals is tentative, and will have to be verified with a larger set of speech material where stress and boundary locations are systematically varied.

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**Fig. 4.** Fundamental frequency patterns as a function of time, for various boundary types (Subject 2).

**REFERENCES**


