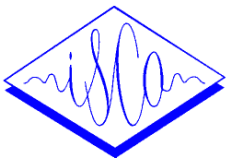

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FACTORS AFFECTING F_0 PEAK DISPLACEMENT IN SPANISH

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ABSTRACT

The aim of the paper is to study the displacement of fundamental frequency (F_0) peaks phonologically associated with lexically stressed syllables in Peninsular Spanish in order to determine some of the factors that can influence this phenomenon. The results show that in paroxyton words in non prepausal position F_0 peaks are shifted at least one syllable to the right of the one bearing the lexical stress. An important effect of the strength of different types of syntactic boundaries and also an effect of pauses have been observed.

1. INTRODUCTION

Fundamental frequency (F_0), together with duration and intensity, is one of the acoustic correlates of stress in Spanish ([1], [2]). The pitch contour of an utterance could then be conceived as a series of local movements consisting of F_0 peaks occurring simultaneously with the lexically stressed syllables. However, preliminary observations presented in [3] showed that, for declarative sentences, F_0 peaks are in more than 70% of cases associated to the syllable that follows the one bearing the lexical stress in the phonological representation. Navarro Tomás ([4]) had already noticed that weak syllables immediately following the first stressed syllable in a breath group frequently have a higher pitch than the stressed one. The model proposed by Fant ([5]) also implies that in initial stress groups F_0 peaks appear in the syllable following the one bearing the lexical stress.

Delays in the F_0 peak corresponding to the syllable bearing the lexical stress have been studied for English by Silverman and Pierrehumbert ([6]), among others, and for Mexican Spanish by Prieto *et al.* ([7]). It is shown in [7] that the timing of the F_0 peak in lexically stressed syllables is influenced by intrasyllabic segmental durations, adjacency to word boundaries, intonational and intermediate phrase boundaries and stress clash.

The aim of the present paper is to explore several factors that might affect displacement of F_0 peaks in Peninsular Spanish: distance between lexical stresses, sentence length, sentence modality and syntactic structure, specially considering different types of syntactic boundaries.

2. EXPERIMENTAL PROCEDURE

2.1. Corpus

A basic sentence structure - [Determiner [Adjective, Noun]] NP (subject) [Verb [Determiner [Noun, Adjective]] NP (object)] VP - has been taken as a starting point for building up the corpus of analysis. This structure allows the comparison of two different types of syntactic boundaries: NP subject-VP and VP-NP object.

All syllables in the sentence are formed by a consonant and a vowel, the most frequent syllabic structure in Spanish ([1]), and all segments -except when adverbs ending in *mente* are included in the modified version of the sentences- are voiced in order to avoid errors and irregularities in pitch detection. However, the effects of unvoiced consonants should be considered in future studies.

2.1.1. Stress pattern

The stress pattern in the head of the subject NP and in the contiguous verb has been varied within the same syntactic structure; in the rest of the sentence, a paroxyton stress pattern has been kept constant. The following combinations have been considered:

(1) proparoxyton nouns and oxyton verbs (e.g. *Débora miró* - 3 syllables between stresses);
(2) proparoxyton nouns and paroxyton verbs (e.g. *Débora doma* - 2 syllables between stresses);
(3) paroxyton nouns and oxyton verbs (e.g. *villano lavó* - 2 syllables between stresses);
(4) paroxyton nouns and paroxyton verbs (e.g. *marino daña* - 1 syllable between stresses);
(5) oxyton nouns and oxyton verbs (e.g. *Mariví miró* - 1 syllable between stresses);
(6) oxyton nouns and paroxyton verbs (e.g. *Mariví roba* - stress clash).

This allows the study of the effect of position of the lexical stress within the word and of the distance between lexically stressed syllables.

2.1.2. Syntactic structure

In order to study the effect of syntactic variation, the basic sentence structure is modified in several ways:

(1) the adjective within the VP can be either a modifier of the direct object or a predicative related to the subject; care

has been taken to avoid ambiguity in those sentences (e.g. *mi rudo villano lavó la lana merina* vs. *mi rudo villano lavó la lana dolido*);
(2) a sentence adverb is placed at three different positions: at the end, at the beginning or in the middle of the sentence (e.g. *mi rudo villano lavó la lana merina, obviamente* vs. *obviamente, mi rudo villano lavó la lana merina* vs. *mi rudo villano, obviamente, lavó la lana merina*);
(3) a manner adverb is added to the VP, alternating with a PP of manner (e.g. *mi rudo villano lavó la lana merina debidamente* vs. *mi rudo villano lavó la lana merina de modo velado*).

These modifications also allow for comparisons between short and long sentences (e.g., *mi duro guerrero ganó la loma romana* vs. *mi duro guerrero ganó la loma romana de manera velada*)

Effects of sentence modality are studied by comparing declarative and direct interrogative sentences (e.g., *la bella Mariví roba la llave dorada* vs. *¿la bella Mariví roba la llave dorada?*). This contrast is expressed in Spanish by means of a different F_0 pattern (falling *vs.* raising).

The final corpus consists of 78 target sentences, to which 108 filler sentences have been added.

2.2. Recordings and speakers

The corpus was read in random order by five male native Peninsular Spanish speakers. Recordings took place in a sound proof room using a Tascam 112 cassette recorder and a Sennheiser MKH20 microphone.

2.3. Measurements

F_0 contours were obtained using the Mac Speech Lab II™ software, which includes a pitch tracking algorithm based on an auto-correlation technique. All F_0 maxima for each sentence have been determined and measured according to the criteria presented in [3]; F_0 maxima are defined at turning points where a change in the F_0 value occurs with respect to the preceding and following syllables. Distance in number of syllables from each lexical stress to the corresponding F_0 peak has been computed for all conditions described above. A total number of 2310 items has been measured (462 items x 5 speakers).

3. RESULTS

3.1. Syntactic boundaries

3.1.1. NP (subject) -VP boundary

When paroxyton nouns occur before an NP-VP boundary, in 82.1% of the cases the F_0 peak is displaced from the lexically stressed syllable to the next one; in 17.9% of cases shift in the peak does not occur.

In proparoxyton nouns before an NP-VP boundary, the F_0 peak corresponding to the lexically stressed syllable is displaced to the syllable immediately preceding the boundary - i.e., two syllables after the stressed one - in 61.5% of cases; displacement to the syllable following the lexically stressed one occurs in 30.7% of cases, while in 7.8% of cases the F_0 peak remains in the lexically stressed syllable.

In oxyton nouns before an NP-VP boundary no peak displacement is found, since the F_0 peak coincides with the lexically stressed syllables in 100% of the cases.

These results are summarized in table 1:

	Oxyton N	Paroxyton N	Proparoxyton N
No shift	100%	17.9%	7.8%
1 syllable shift		82.1%	30.7%
2 syllables shift			61.5%

Table 1: Percentage of F_0 peak displacements in oxyton, paroxyton and proparoxyton nouns (N) in an NP subject - VP boundary

It can be concluded from the results obtained that: (a) there is no peak displacement across an NP subject -VP boundary; and (b) F_0 peaks appear in more than 80% of cases in the syllable immediately preceding the boundary, irrespective of the lexical stress pattern of the noun preceding it.

3.1.2. VP - NP (object) boundary

In oxyton verbs next to a VP-NP object boundary, the F_0 peak corresponding to the lexically stressed syllable is displaced one syllable across the boundary in 63.4% of cases. In paroxyton verbs, displacement across the boundary does not occur, since in 93.3% of cases the F_0 peak is shifted to the syllable following the lexically accented one.

Table 2 summarizes these results:

	Oxyton V	Paroxyton V
No shift	36.6%	6.7%
1 syllable shift	63.4%	93.3%

Table 2: Percentage of F_0 peak displacement in oxyton and paroxyton verbs (V) in a VP - NP object boundary

The difference between the percentage of cases in which displacement occurs in oxyton and paroxyton verbs can be explained by the presence of a syntactic boundary immediately after the lexically stressed syllable in oxyton verbs; in paroxyton verbs, the boundary appears one syllable after the lexically stressed one. In the former case, the VP-NP object boundary would partially inhibit peak displacement.

3.1.3. Noun-Adjective vs. Noun-Predicative boundary

In the corpus studied, VPs in declarative sentences consist either in a direct object with an adjective modifying the noun or in a predicative modifying the subject. This allows the comparison of two types of syntactic boundaries: between the noun and its adjective and between the noun and a predicative related to another noun. Results in table 3 show that F_0 peaks corresponding to the lexically stressed syllable in the noun are equally displaced in both cases:

	N before predicative	N before adjective
No shift	13.3%	23.2%
1 syllable shift	86.7%	74%
2 syllable shift		2.7%

Table 3: Frequency of F_0 peak displacement in paroxyton nouns (N) before predicatives and before adjectives

3.2. Pauses

Since the corpus includes paroxyton words in different sentence positions, their behaviour in prepausal and non prepausal position can be studied.

In paroxyton adjectives in final sentence position the F_0 peak remains in the lexically stressed syllable in 93.9% of cases; when the same type of adjective precedes an internal sentence pause - i.e., when a sentence adverb preceded by a pause is introduced after the adjective - the same behaviour of the F_0 peak is found, the peak remaining at the lexically stressed syllable in 95.7% of cases. These results can be compared with those obtained for paroxyton adjectives in the same context but not followed by a pause; in this case, the F_0 peak remains at the stressed syllable in 10.8% of cases, being displaced one syllable to the right in 84.3% of cases and two syllables to the right in 2.4% of cases.

In paroxyton nouns followed by a pause in internal sentence position, the F_0 peak is not displaced from the lexically stressed syllable in 100% of cases. As reported before, in paroxytons nouns in NP-VP boundaries where no pause was produced by the speakers, only 17.9% cases of lack of peak displacement have been found.

The results obtained for nouns and adjectives in prepausal position are presented in table 4:

	Internal pause		Final pause
	Nouns	Adjectives	Adjectives
No shift	100%	95.7%	93.9%
1 syllable shift		4.3%	6.1%

Table 4: F_0 peak displacements in nouns and adjectives followed by internal or final sentence pauses.

When sentence adverbs - with stress in the penultimate syllable - at the beginning of a sentence and followed by a pause are considered, it is observed that the F_0 peak is displaced to the syllable immediately preceding the pause in 75% of cases. This is not the case for sentence adverbs in medial sentence position, where shift is found only in 25% of cases (See Table 5).

	Initial sentence position	Medial sentence position
No shift	25%	51.6%
1 syllable shift	75%	25%

Table 5: F_0 peak displacements in sentence adverbs in initial and medial sentence position

The different behaviour of initial and medial sentence adverbs remains to be explained, although it could be hypothesized that it is related to differences in their pragmatic function due to word order.

The preceding data can be interpreted as suggesting an important effect of pre-pausal position in paroxyton nouns and adjectives; in this position the F_0 peak tends to remain in the lexically stressed syllable. The opposite trend is observed in initial sentence adverbs, where F_0 peak displacements are found before pauses.

3.3. Sentence length

Since the corpus comprises sentences that have been lengthened by the addition of a PP at the end, it is possible to study the effect of sentence length in peak displacements.

It has been observed that sentence length does not affect the behaviour of F_0 peaks as far as paroxyton words are concerned.

3.4. Sentence modality

Interrogative sentences show almost the same basic trend in the behaviour of proparoxyton nouns immediately preceding an NP-VP boundary, although more variability has been found in oxyton and paroxyton nouns.

In oxyton nouns, the F_0 peak remains at the lexically stressed syllable in 57.1% of cases, while in 42.9% of cases the peak is displaced to the next syllable.

In 57.8% of paroxyton nouns the F_0 peak is displaced to the syllable following the lexically stressed one, and in 10.6% of cases it is displaced to the second syllable after the one bearing the lexical stress; in 31.6% of cases the F_0 peak remains at the lexically stressed syllable.

The F_0 peak in proparoxyton nouns appears in the last syllable of the word in 85.7% of the cases, while displacement to the penultimate syllable occurs in 14.3% of cases.

	Oxyton N	Paroxyton N	Proparoxyton N
No shift	57.1%	31.6%	
1 syllable shift	42.9%	57.8%	14.3%
2 syllables shift		10.6%	85.7%

Table 6: Percentage of F_0 peak displacements in oxyton, paroxyton and proparoxyton nouns (N) in an NP subject - VP boundary in interrogative sentences

Globally, results concerning the presence of a displacement across a syntactic boundary can be summarized as follows:

NP subject - VP	
Shift across boundary	Lack of shift across boundary
17.8%	82.2%

Table 7 : Percentage of F_0 peak displacement across NP subject - VP boundaries in interrogative sentences

Although the results are not as conclusive as for declarative sentences, a similar trend to avoid peak displacement before a NP subject - VP boundary is also observed for interrogative sentences.

4. DISCUSSION AND CONCLUSIONS

As it was already observed in [3], a general tendency towards a displacement of the F_0 peak to the right of the lexically accented syllable has been found. This tendency is consistent for all lexical categories present in the corpus that can be considered to appear in an unmarked situation, i.e., in paroxyton words - which amount to 79.5% of the non monosyllabic words in Spanish ([1]) - in non prepausal position. Table 8 summarizes the results obtained for the different lexical categories:

	No shift	1 syllable shift	2 syllables shift
Adjective in NP subject		98.8%	1.2%
Adjective in NP object + adverb	7.4%	85.2%	7.4%
Adjective in NP object + PP	13.3%	84.6%	2.1%
Noun in NP subject	17.9%	82.1%	
Noun in NP object	23.3%	74%	2.7%
Verb	6.7%	93.3%	

Table 8: Frequency of F_0 peak displacement in paroxyton adjectives, nouns and verbs in non prepausal position

Results in table 8 can be compared with those presented in table 4 concerning shifts in prepausal position. The effect of pauses - either medial or final - as inhibitors of peak displacement clearly appears in the data observed, showing a different behaviour of F_0 contours in terminal and non terminal positions in the breath group.

In order to study the effect of different types of syntactic boundaries in F_0 peak displacement from the lexically accented syllables, two main types of boundaries in declarative sentences can be compared: NP subject - VP and VP - NP object. In NP-VP boundaries, more than 80% of F_0 peaks occur in the syllable immediately preceding the boundary irrespective of the stress pattern of the noun; for oxyton nouns, this observation is valid in 100% of the cases. The same pattern of results has been observed for interrogative sentences, although the differences in percentage of shift are less clearly marked. On the other hand, in 68.3% of verbs in a VP - NP boundary no shift across the boundary has been found.

The two types of syntactic boundaries can be distinguished by observing the percentage of peak displacements across boundaries presented in table 9:

NP subject - VP		VP - NP object	
Shift across boundary	No shift across boundary	Shift across boundary	No shift across boundary
0%	100%	31.7%	68.3%

Table 9 : Percentage of F_0 peak displacement across boundaries as a function of the type of syntactic boundary in declarative sentences

These data show an important difference between both types of boundaries in terms of their effect in F_0 peak displacements. Strong boundaries such as NP subject - VP would inhibit peak displacement, and F_0 peaks could act as a prosodic marker of the boundary. In weaker boundaries, such as VP-NP object, this would not be the case, since shifts across the boundary would be allowed in some cases, as evidenced by the behaviour of oxyton verbs. The lack of difference between Noun-Adjective and Adjective-Predicative boundary (*cf.* 3.1.3) needs to be explored in more detail in further studies.

It can be concluded that, at least in the highly controlled corpus used in this study, there is a clear tendency towards F_0 peak displacement in paroxyton words - the unmarked category in Spanish - in non prepausal position. The strength of the syntactic boundary (NP subject - VP *vs.* VP - NP object) and the presence or absence of pauses seem to be important factors affecting the shifting of F_0 peaks phonologically associated with lexically stressed syllables. Sentence length and modality do not seem to have a strong influence on this phenomenon.

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