

# Phonetic and phonological properties of the final pitch accent in Catalan declaratives

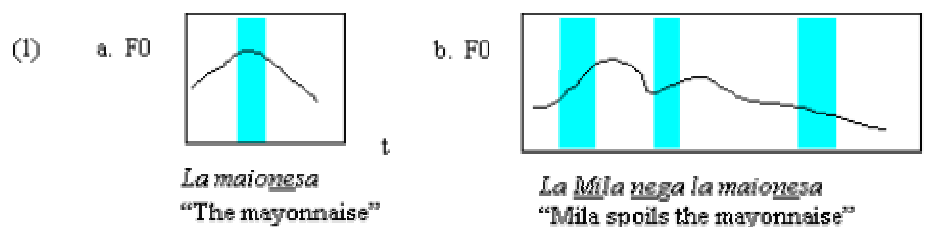
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## Abstract

This paper examines the phonetic and phonological properties of the last pitch accent in Catalan single and multi-stressed neutral declaratives. Traditionally, the different F0 patterns observed in single stressed structures (clear F0 peak) and in multi-stressed structures (progressively falling slope or a strongly lowered F0 peak) have been subject to different phonological interpretations (H\* and L\* respectively). In this study, acoustic and perceptual evidence is provided to show that the different F0 patterns should be interpreted as realisational differences of the same phonological entity (H\*).

## 1. Introduction

The aim of this paper is to examine the phonetic and phonological properties of the last pitch accent in Catalan neutral declaratives within the Autosegmental-Metrical approach of intonational analysis (Ladd, 1996). Previous studies on the intonation of Catalan declaratives (Bonet, 1984 ; Prieto, 1995, 2002 ; Estebas-Vilaplana, 2000) have shown that the phonetic properties of the final pitch accent differ depending on the number of accents in the utterance. If the utterance consists of one stressed item, an F0 rise is observed within the accented syllable followed by a fall. A schematised F0 trace is illustrated in (1a) below for the phrase *la maionesa* with stress on the penultimate syllable (underlined). The shaded box indicates the limits of the accented syllable. If there were no post-stressed syllables, the whole rise-fall movement would be compressed on the accented syllable. In multi-stressed sentences, on the other hand, the final accent shows no drastic F0 change within the limits of the accented syllable but exhibits a falling movement which usually starts after the last pre-nuclear accent, and progressively falls till the end of the utterance. This is illustrated in (1b) below for a sentence which consists of two pre-nuclear rising accents before the final one.



The different phonetic properties observed in the F0 traces of single and multi-stressed utterances in Catalan have been subject to different phonological representations. Prieto (1995) proposes an H\* pitch accent associated to the accented syllable of single-stressed utterances and an L\* for the last accented syllable of multi-stressed utterances. This interpretation, however, is problematic since two phonological entities (L\* and H\*) are used to describe two intonation patterns which do not trigger a contrastive opposition since in both cases the meaning conveyed is that of a neutral, unmarked declarative. The aim of this study is to test the hypothesis that the same phonological unit (H\*) can be used to represent the last pitch accent of both single and multi-stressed declarative sentences and that the lack of an obvious F0 peak in multi-stressed sentences can be interpreted as a phonetic realisation of H\*, in particular, as the result of final lowering (Pierrehumbert and Beckman, 1988). *Final lowering* is a sentence-level phenomenon whereby the final H\* of a sentence undergoes a more drastic lowering in F0 than that of the previous F0 peaks. The existence of final lowering has been reported in many languages (English : Pierrehumbert and Beckman, 1988 ; Japanese : Beckman and Pierrehumbert, 1986 ; Mexican Spanish : Prieto et al., 1996 ; German : Möbius, 1993 ; Grabe, 1998, among others).

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In order to test the hypothesis that the same phonological primitive (H\*) can be used to describe the last pitch accent of both single and multi-stressed declaratives, two kinds of tests were carried out, namely, a production test and a perception test. The aim of the production test is to examine the scaling and the alignment properties of the final accent in single and multi-stressed utterances so as to investigate whether the two F0 movements can be interpreted as realisational differences of the same accent type or not. The aim of the perception test is to check whether the two pitch contours are judged as linguistically different entities or are perceived as the same tonal category.

## 2. Production test

### 2.1. Experimental procedures

For the production test 64 single-stressed declaratives and 64 multi-stressed declaratives were designed. The single-stressed structures consisted of the last Noun Phrase (i.e. determinant plus noun) of multi-stressed sentences. This allowed us to compare the F0 movements of the last pitch accent of multi-stressed sentences with that of single-stressed structures with no variation in the segmental string. In single stressed structures, the accent always fell on the stressed syllable of the noun. The number of stresses in multi-stressed sentences were 3 or 4. One female speaker of the Central variety of Catalan was asked to read the sentences as if they were answers to a “what happens?” type of question, that is, with a neutral, unmarked intonation. Sentences were designed with the maximum number of voiced segments possible so as to avoid too many breaks in the F0 contours. Overall, 128 utterances were gathered. The recordings included *speech* and *laryngeal* signals. For the speech signal, a Marantz Superscope/CD 330 tape recorder and a Beyer Dynamic microphone were used. For the laryngeal signal, a portable laryngograph LX 12 with two electrodes was used. A Thandar portable DRO 26 oscilloscope was also used to check the activity of the vocal folds. The acoustic analysis was carried out by means of the Speech Filing System (SFS) program, which allowed us to perform a time-aligned inspection of the speech waveform and the F0 trace.

### 2.2. Results

As expected, the F0 traces of single-stressed utterances showed an F0 rise within the limits of the accented syllable. In multi-stressed sentences, on the other hand, two different patterns were observed. In the majority of cases (76%), the last pitch accent exhibited a non-rising F0 excursion but a progressively falling F0 movement which started after the last pre-nuclear accent. This is illustrated in Figure 1, which exhibits the speech waveform and the F0 trace for the sentence *La Mila nega la maionesa*. The onset of each syllable is marked in the box at the bottom of the graph. However, in 24% of the cases a slight F0 rise, less drastic than that of single-stressed utterances, was observed within the limits of the last accented syllable. An example is provided in Figure 2 for the sentence *L'Elena mira de moure el mobiliari* produced with three pitch accents. The final accent falls on the stressed syllable of the last lexical word and shows a slight F0 rise which is much lower than the F0 peaks observed in pre-nuclear accents.

Even though in these cases the F0 rise was not very abrupt, it still allowed us to carry out a comparison with the single-stressed utterances so as to examine the scaling and the alignment of the F0 peak and determine whether the two F0 movements correspond to the same phonological entity or not. The predictions were as follows : if the final pitch accent is H\*, 1) the alignment of the F0 peak within the accented syllable is expected to show no differences in single and in multi-stressed declaratives, and 2) the scaling of the F0 peak is expected to be much lower in multi-stressed utterances than in single-stressed utterances due to a final lowering effect.

As far as the F0 alignment is concerned, the following measurements were taken for the last pitch accent of single and multi-stressed utterances : 1) distance between the onset and the offset of the accented syllable (i.e. duration of the accented syllable), and 2) distance between the onset of the accented syllable and the F0 peak. The results are displayed in Table 1, which shows the mean values of the following measurements : 1) F0 peak position (expressed as % of the duration of the accented syllable), 2) duration of the accented syllable (on-of), and 3) distance between the onset of the accented syllable and the F0 peak (on-p).

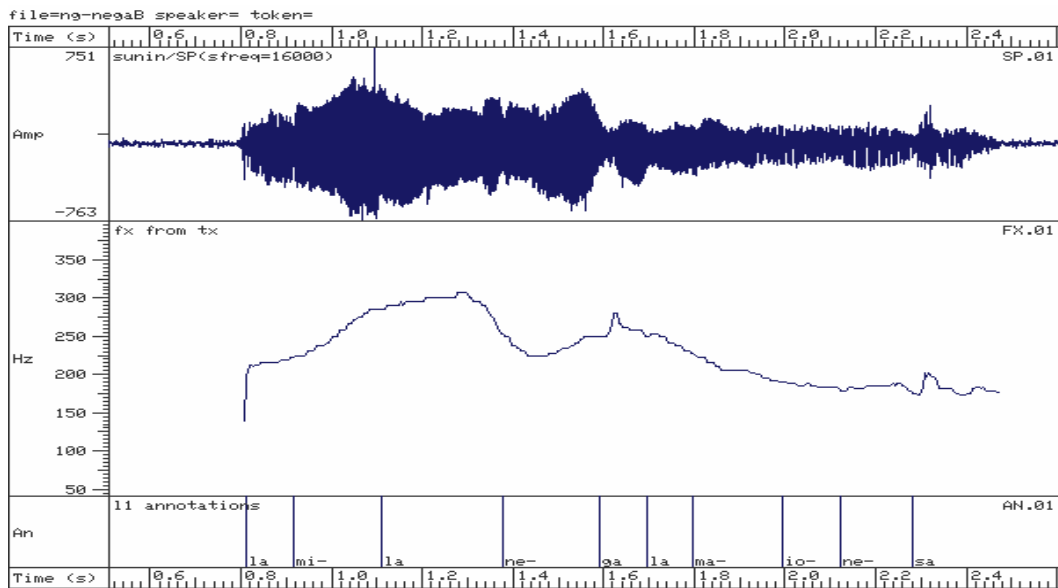


Figure 1. Speech waveform and F0 trace for the sentence. *La Mila nega la maionesa* (Mila spoils the mayonnaise).

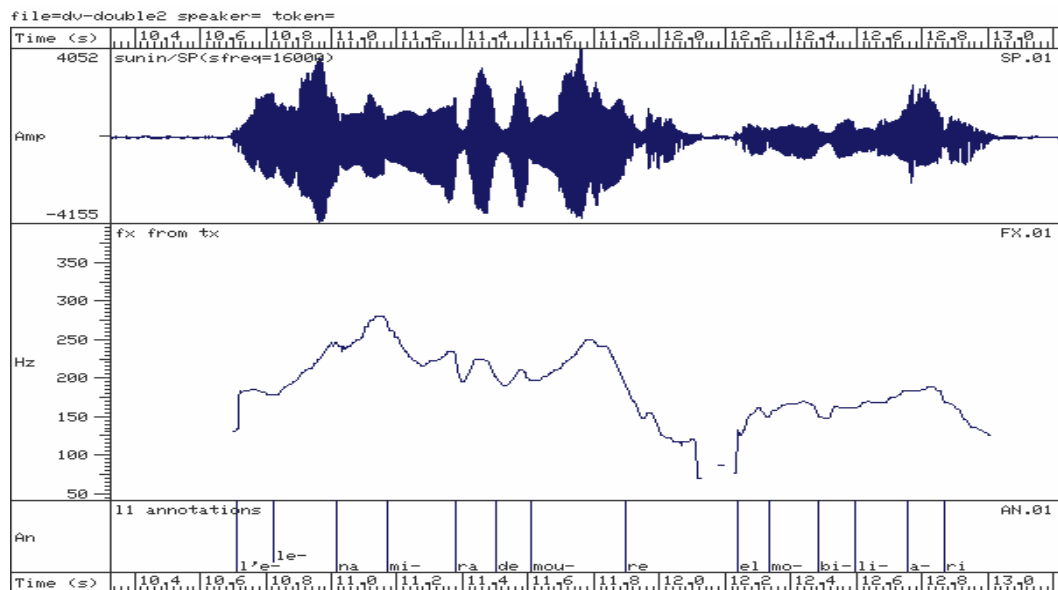


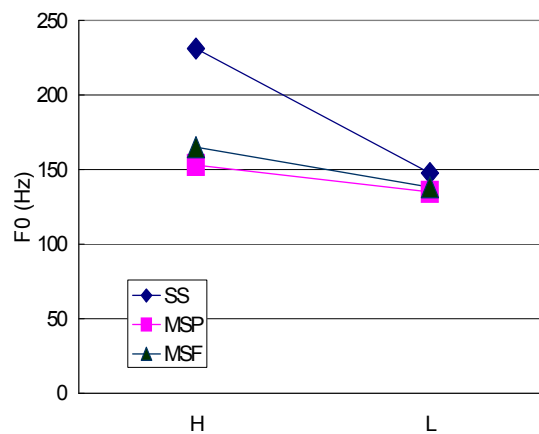
Figure 2. Speech waveform and F0 trace for the sentence. *L'Elena mira de moure el mobiliari* (Helen tries to move the furniture).

The results on the alignment of the F0 peak with respect to the accented syllable show that the F0 peak is located near the end of the accented syllable both in single and in multi-stressed declaratives. In single-stressed utterances, the F0 peak is positioned at 88.9% of the duration of the accented syllable, whereas in multi-stressed utterances it is located at 90.7%. A t-test confirmed that the differences in the mean values of F0 peak position were not significantly different ( $p > 0.01$ ). These results show that single and multi-stressed structures behave very similar with respect to the alignment of the F0 maximum and hence both accents seem to respond to the same phonological entity (H\*).

	Single-stressed utterances	Final accent of multi-stressed utterances
F0 peak position (%)	88.9	90.7
on-of (s)	0.181	0.173
on-p (s)	0.161	0.157

**Table 1. Mean values of F0 peak position (expressed as % of the syllable duration), syllable duration (on-of) and distance between the onset of the accented syllable and the F0 peak (on-p) in seconds for the final accent of single and multi-stressed utterances.**

For the analysis of the F0 scaling, the following measurements were taken : 1) F0 maximum of the pitch accent in single-stressed utterances, 2) F0 maximum of the last pitch accent in multi-stressed utterances, and 3) phrase final F0 value. In those cases where the final accent of multi-stressed sentences was realised as a continuously falling slope, the highest F0 value was located at the beginning of the accented syllable. The results are plotted in Figure 3 which exhibits the mean F0 maximum of the last pitch accent and the mean phrase final F0 value for SS (single-stressed utterances), MSP (multi-stressed utterances with a final peak), and MSF (multi-stressed utterances with a falling slope).



**Figure 3. Mean F0 maximum of the last pitch accent (H) and the mean phrase final F0 value (L) for SS (single-stressed utterances), MSP (multi-stressed utterances with a final peak), and MSF (multi-stressed utterances with a final accent produced with a falling slope).**

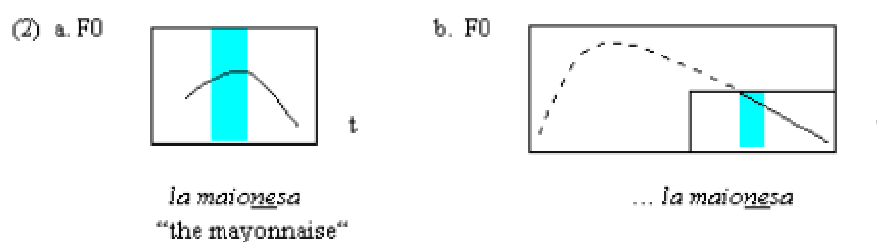
As expected, the results show that the F0 peak of single-stressed sentences is much higher (mean F0 peak: 231 Hz) than that of multi-stressed utterances produced both with a slight F0 peak (mean F0 peak: 153 Hz) and without a peak (mean F0 “peak”: 165 Hz). T-tests comparing the F0 peak values of SS with those of MSP and MSF confirmed that the F0 peak values in single-stressed sentences are significantly higher ( $p < 0.01$ ) than the F0 peak values in multi-stressed sentences. However, a t-test comparing the F0 peak values of MSP and MSF showed that there are no significant differences ( $p > 0.01$ ) between the two samples. These results suggest the presence of final lowering in Catalan declaratives produced with more than one pitch accents as opposed to single-accented utterances. Furthermore, they show that the scaling of the F0 peak in MSP and MSF is very similar and therefore a final falling slope or a slight F0 peak can be interpreted as realisation differences of the same pitch accent (H\*). The interpretation of the final pitch accent as H\* in all kinds of utterances is corroborated by the falling F0 excursion observed between the H and the L in Figure 3. If the accent was L\*, a linear interpolation would be expected between L\* and the following edge tones (L-L%). However, in all cases the interpolation between the two targets shows a falling line indicating the movement from an H target (H\*) to an L target (L-L%). Thus, the results obtained in this study concerning the scaling and the alignment of the final F0 peak in Catalan declaratives seem to corroborate the idea that the last pitch accent of a multi-stressed declarative is not an L\* pitch accent but a strongly lowered H\*.

### 3. Perception test

#### 3.1. Experimental procedures

In order to confirm the interpretation of the last pitch accent of both single and multi-stressed sentences as H\*, a perceptual test was also carried out. The aim of the perception test was to investigate whether the speakers perceived the non-lowered pitch accent observed in single-stressed utterances as different in meaning from the (strongly lowered) accent of multi-stressed sentences. If the two F0 patterns are judged to convey a different meaning, then two tonal entities should be used to describe each pattern. If, on the other hand, no differences in meaning are perceived with the two patterns, then they should be interpreted as realisational differences of the same phonological primitive.

The stimuli used in the perception test were the single-stressed phrases obtained in the production test, as in (2a), as well as the last accented phrase of multi-stressed sentences, where the pre-nuclear portion was removed, as in (2b). In order to remove the pre-nuclear section, the SFS program was used, which allowed us to break the signal into different speech chunks and exclude the selected parts. Then, the data was transferred into a 60 ES DAT recorder.



As distractors, the same 64 single-stressed phrases were used with a different intonation pattern, namely, a rising intonation (typical of questions) and a level intonation (as in monotonous repetitions). Those structures were recorded by the same speaker that performed the production test in a later recording session. The perception test included 128 pairs of utterances which consisted of any possible combination of the four intonation patterns, namely, the two target patterns (i.e. single-stressed structures produced with a clear F0 peak and the last portion of multi-stressed structures produced with no F0 peak or a strongly lowered one) and the two distractors (structures with a rising or a level F0 pattern). Each pair consisted of the same two phrases in terms of segmental structure but produced with a different F0 pattern. For each pair, the speakers were asked to say whether the meaning of the two structures was the same or different with respect to its intonation. From the 128 pairs presented to the informants, 64 were combinations of the two target patterns, and 64 combinations of a target pattern and a distractor or two distractors. The perceptual test was performed by two Central Catalan female speakers. The stimuli were played in a 60 ES DAT recorder. The informants were given the list of pairs on a written paper and they were asked to decide whether they perceived them as different in meaning or not. The list of pairs was played twice.

#### 3.2. Results

The results of the perception test are presented in Table 2. Both informants perceived no differences in meaning for the target pairs, i.e. single-stressed phrases produced with a non-lowered F0 peak and the last accent of multi-stressed structures produced with no F0 peak or a strongly lowered one. Thus, the auditory impression of the two informants was that when heard in isolation lowered H\* accents sounded very similar to non-lowered H\* accents (produced with a low register). Similar observations are reported in Grabe (1998) for German. As expected, pairs including distractors were judged to convey a different meaning.

	Same meaning		Different meaning	
	Speaker 1	Speaker 2	Speaker 1	Speaker 2
Pairs with target patterns ( <i>lowered &amp; non-lowered H*</i> )	64	64	-	-
Pairs with distractors	-	-	64	64

Table 2. Results of the perception test for the two speakers.

#### 4. Discussion

The results of the production and the perception tests show that the distinction between non-lowered accents (in single-stressed utterances) and lowered accents (last accent of a multi-stressed sentence) in Catalan declaratives seems to be gradient rather than categorical. The production test shows that a non-lowered H\* and a strongly lowered H\* (with a slight F0 peak) present no major differences as far as the alignment is concerned. As far as the scaling is concerned, the F0 maximum of the final accent in multi-stressed sentences is much lower than that of single-stressed utterances, indicating the presence of final lowering in multi-stressed structures. The similarities in the scaling of the F0 maximum obtained for those accents produced with a progressively falling slope and those realised with a slight F0 peak in multi-stressed utterances indicate that the two patterns can be interpreted as different realisations of the same phonological entity. Similar results were reported in Prieto et al. (1996) for Mexican Spanish where the last H\* accent of declarative sentences could be realised as a slight F0 peak or with a progressive fall. The results of the perception test confirm the interpretation of the last pitch accent in single and in multi-stressed sentences as H\* since the speakers perceived no differences in meaning despite differences in the scaling of those accents. The findings presented in this paper throw into doubt Prieto's (1995) proposal for treating the two accents as phonologically distinct and support the idea of analysing the two contours as different realisations of a single tone (H\*). Thus, the intonational behaviour of the final pitch accent in single and in multi-stressed Catalan sentences can be interpreted as a single category (H\*) which is subject to realisational differences (i.e. without final lowering in single-stressed utterances and with final lowering in multi-stressed utterances).

#### 5. Conclusion

In this paper the phonetic and phonological properties of the last pitch accent in Catalan single and multi-stressed neutral declaratives has been examined within the Autosegmental-Metrical approach of intonational analysis. This paper has shown that the different F0 patterns observed in single stressed structures (clear F0 peak) and in multi-stressed structures (progressively falling slope or a strongly lowered F0 peak) respond to the same phonological interpretation (H\*). Acoustic evidence showed that there were no differences in the alignment of final F0 peaks in single and in multi-stressed structures (when the F0 peak was present), and that differences in the scaling of such peaks could be interpreted as a final lowering effect on sentences with more than one pitch accent. The results of the perceptual study showed that the two F0 patterns observed in single and in multi-stressed sentences were not contrastive since the speakers did not perceive any differences in meaning. Thus, the different F0 patterns observed on the last pitch accent of single and multi-stressed neutral declaratives in Catalan can be described as realisational differences of the same phonological entity (H\*).

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