

# Stress and Accent in Catalan and Spanish: Patterns of duration, vowel quality, overall intensity, and spectral balance\*

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## Abstract

This article is concerned with the acoustic correlates that characterize stress and accent in Catalan and Spanish. We analyzed four acoustic correlates of stress (syllable duration, vowel quality, overall intensity, and spectral balance) in four conditions, namely, stressed and unstressed syllables in both accented and unaccented environments. This allowed us to examine the relative strength of these correlates and see how they interacted with the presence versus absence of a pitch accent. Given that Spanish and Catalan differ greatly in the way they use vowel reduction to mark stressed positions (Catalan has a phonological process of vowel reduction that affects all vowels except [i] and [u]), the goal of this study is to test whether they will also differ in the way they use the other acoustic correlates (duration and intensity) to signal the presence of stress and accent. Our results revealed no great differences between the two languages' use of acoustic cues. Along with the findings of Slujter & collaborators [1], [2], [3] and Campbell & Beckman [4] on Dutch and English, Catalan and Spanish reveal systematic differences in the acoustic characterization along the accent and stress dimensions. Specifically, while syllable duration, vowel quality, and spectral tilt are reliable acoustic correlates of the stress difference in both languages, accentual differences are acoustically marked by overall intensity cues.

## 1. Introduction

Work by Slujter & collaborators and Beckman & collaborators was among the first to examine the acoustic and perceptual correlates of stress without the confounding effects of accent [1], [2], [3]. They found that when a Dutch word is unaccented, the stressed syllable can still be distinguished both acoustically [1] and perceptually [3]. Their results revealed that stress is cued by duration, intensity, and vowel quality in the absence of an accent. Importantly, they showed that duration and spectral balance differences (that is, intensity differences at the higher frequencies of the spectrum) were strong correlates of the stress difference, while overall intensity was a cue of accent rather than stress. On the perceptual side, they showed that stressed unaccented syllables in Dutch could be distinguished from their unstressed counterparts due to a combination of longer duration, greater spectral balance and absence of segmental reduction, even without the presence of a pitch accent. Thus, both spectral balance and duration differences were strong cues to the identification of stress in Dutch. Work on American English [2], [4] confirmed the main results found for Dutch, namely, that stressed syllables are longer than unstressed syllables, regardless of accent, and that overall intensity mainly cues accent, not stress.

The goal of this article is to examine patterns of duration, overall intensity, spectral balance, and vowel quality in words bearing a prenuclear pitch accent and in words bearing no pitch accent, with the intention of expanding the findings of Slujter & collaborators and Campbell & Beckman for Dutch and American English respectively. It is expected that, similarly to Dutch and English, we will find systematic phonetic differences in the acoustic characterization along the accent and stress dimensions. We are especially interested in analyzing the role of intensity (and spectral balance) as correlates of accent and stress, as there are contradictory reports in the literature. Finally, we also ask ourselves whether the fact that Spanish has practically no vowel reduction in unstressed positions might interact with the perceptibility of stress and the strength of phonetic cues in the stressed/unstressed dimension, as hypothesized by Campbell & Beckman (1997).

## 2. Methods

### 2.1. Materials

The target words consisted of 15 verbs for each language that ended in “-*minar*” or “-*nimar*”, and were cognates in Catalan and in Spanish, like *determinar* ‘to determine’, *iluminar* ‘to illuminate’, *abominar* ‘to detest’, *desanimar* ‘to discourage’. Each verb was conjugated in the present tense and in the preterit in order to obtain the endings “-*mina/-minà*” for Catalan and “-*mino/-minó*” for Spanish.

Each of the 15 four-syllable verbs was embedded in segmentally identical utterance fragments that were spoken either with a declarative intonation or with the flat intonation of parenthetic sentences. As is well-known, parenthetic utterances are a type of extra-sentential element which has been described as prosodically detached and deaccented in a variety of languages. Thus utterances were produced with 2 different intonation contours: (1) bore a prenuclear accent like in *Me desanimó Catalina* ‘Catalina discouraged me’; (2) did not have an accent, like in parenthetic sentences such as *Va a llover —me desanimó Catalina* ‘It’s going to rain —Catalina discouraged me’.

Thus, for each verb, we obtained the 4-way contrast shown in Table 1. Note that the [+accent] / [-accent] contrast takes place only in declarative sentences, while the [+stress] / [-stress] contrast takes place in both declarative and parenthetic sentences.

Consequently, our test materials allowed us to disentangle the effects of stress from those of accent on different acoustic correlates. The data resulted in a total of 600 syllabic tokens:

2 syllabic positions (ultimate, penultimate) x 2 utterance-types (declarative, parenthetic) x 15 verbs x 5 subjects x 2 languages (Spanish, Catalan).

	Declarative sentences	Parenthetic sentences
[+stress] paroxytone verbs	[+accent] (a) Me desan <u>im</u> o con facilidad	[-accent] (c) No entiendo las matemáticas —me desan <u>im</u> o con facilidad
[-stress] paroxytone verbs	[-accent] (b) Me desan <u>im</u> ó Catalina	[-accent] (d) Va a llover —me desan <u>im</u> ó Catalina

Table 1: Target syllable *ni* (in bold) in four accent/stress contexts.

## 2.2. Subjects

Five native speakers of Central Catalan and five native speakers of Barcelona Spanish participated in the production experiment. Their ages ranged from 24 to 42 years old. All subjects were university students or had earned university degrees and spoke an educated variety of their Spanish or Catalan dialect with their parents and siblings at home. Later in school they learned either Catalan or Spanish as their second language. No subject reported having speech or hearing problems.

## 2.3. Acoustic measures

Measures of duration, vowel quality, spectral tilt, and overall intensity were taken for each target vowel. Duration is measured in milliseconds. Vowel quality for each token was computed as the difference between F2 and F1. Following Sluiter & van Heuven (1996), we estimated intensity as both overall intensity and spectral tilt (or spectral balance). After normalizing all tokens for loudness at -10 dB SNR, overall intensity was estimated using the command ‘Get intensity’ from Praat over the stable part of each vowel. To obtain the measures of spectral tilt, we extracted the amplitudes of two frequency bands (band 1 0-400 Hz, and band 2 400- 4000 Hz). Band 1 contains F0 while band 2 contains the vowel formants. This procedure could not be performed on vowel [i], because F1 frequency is too low to be separated from F0. The spectral tilt of the vowel was then computed as the ratio of band 2 to band 1. A score closer to 1 indicates that the intensity from the lower frequencies is similar to that in the highest frequencies, while a score closer to 0 shows that the intensity of that vowel concentrates in the lower band.

## 2.4. Statistical analysis

We first performed a Repeated Measures ANOVA on the stressed vowels with the factors vowel ([i], [o]) and accent (+accent/-accent) on the measurements of pitch range in order to verify that accented vowels bear a pitch accent while unaccented vowels do not. As for duration, vowel quality, spectral tilt and overall intensity, we performed two statistical analyses. First, we ran a Repeated Measures ANOVA with stress (+/- stress) and intonation (declaratives/parenthetic sentences) as main factors on each vowel ([i]/[o]) for each set of measurements. Second, in order to investigate the contribution of each set of measurements in the prediction of

stress we carried out a Linear Discriminant Analyses (LDA) with duration, vowel quality, spectral tilt, and overall intensity as the predictor variables and stress or accent as the criterion variables.

## 3. Results

### 3.1. Pitch range differences across accent conditions

In order to check whether lexical stress was consistently cued by a pitch accent in declarative sentences, in contrast with parenthetic utterances, we took accentual pitch range (or the distance between the valley and the following peak) to be a measure of F0 variation. In cases in which the pitch was totally flat and no peak and valley could be visually identified, the pitch measures were taken at the beginning and at the end of the target syllable. A Repeated Measures ANOVA revealed highly significant effects of the accent factor on F0 variation (measured as pitch range) for the two languages, confirming a significant pitch increase in the stressed syllables of declarative sentences but not in those of parenthetic sentences.

### 3.2. Duration

The four graphs in Figure 1 plot the confidence intervals for the mean of the penultimate syllable *mi* (left panel) and word-final syllable *no* (Spanish) or *na* (Catalan) (right panel) in different stress (stressed/unstressed) and intonation (declarative/parenthetic) conditions for all speakers of the two languages (Catalan, upper panels; Spanish, lower panels).

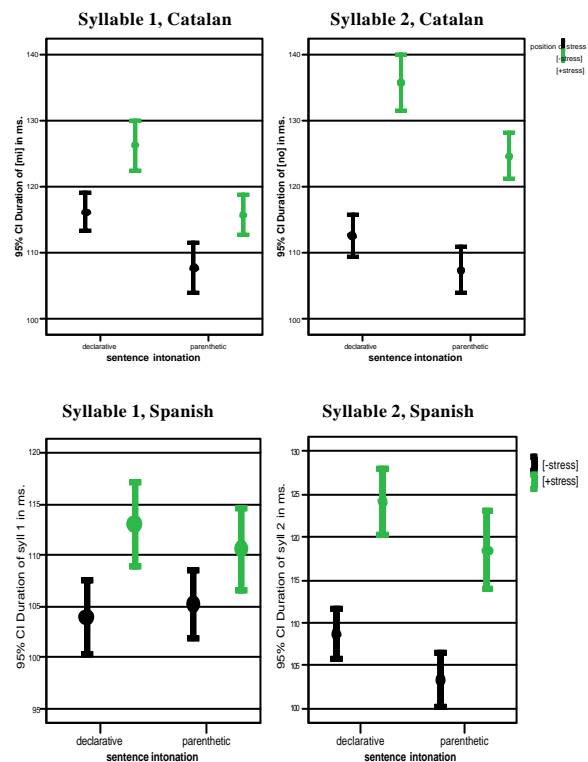


Figure 1: Mean syllable duration and standard error (in ms) of the penultimate syllable (left panels) and word-final syllable (right panels) in different stress (stressed/unstressed) and intonation (declarative/parenthetic) conditions in Catalan (upper panels) and in Spanish (lower panels).

The graphs show that stressed syllables (in grey) are systematically longer than unstressed syllables (in black), and most importantly, that this difference is maintained across intonation contexts, meaning that stressed syllables are longer, even in unaccented environments (a mean difference of 8 ms. for syllable 1 and 15 ms. for syllable 2 in Spanish, and mean difference of 4 ms. for syllable 1 and 10 ms. for syllable 2 in Catalan). Moreover, the magnitude of lengthening of the factor [stress] is greater in word-final syllables than in penultimate syllables in both languages. Second, we find no consistent patterns with respect to the potential lengthening effects of accent: while accented syllables are longer in Catalan, only word-final accented syllables are longer in Spanish. Importantly, though, the magnitude of lengthening exerted by the presence of stress is higher than that of an accent.

Results from a Repeated Measures ANOVA with the factors of stress (+stress/-stress) and intonation (declarative/parenthetic) on the duration of syllables 1 and 2 reveal that the main factor of stress was significant at  $p < .0001$  for the duration of the two syllables in both languages, while the main factor of accent was significant for only one of the two syllables. The interaction 'stress\*intonation' was non-significant, meaning that stressed syllables were longer than unstressed syllables in both accented and unaccented contexts. We conclude that duration is a strong acoustic correlate of the *stress* difference in both languages, but not of the presence of an *accent*. In our data, the presence of an accent does not obligatorily trigger lengthening on the stressed syllable.

### 3.3. Vowel Quality

The two graphs in Figure 2 show the mean confidence intervals for the mean F2-F1 difference in Barks for the word-final vowels [a] (Catalan, left panel) and [o] (Spanish, right panel) in different stress (stressed/unstressed) and intonation conditions (declarative/parenthetic). The graphs reveal that both vowels display a quality difference between stressed and unstressed positions. The distance between F1 and F2 in Barks is larger in unstressed [o] and [a] than it is in their stressed counterparts, showing that stress changes the quality of those vowels by decreasing the distance between F2 and F1. No vowel quality changes were observed for [i] in stressed vs. unstressed positions in either of the two languages. Finally, the graphs reveal no clear effects of the presence of an accent.

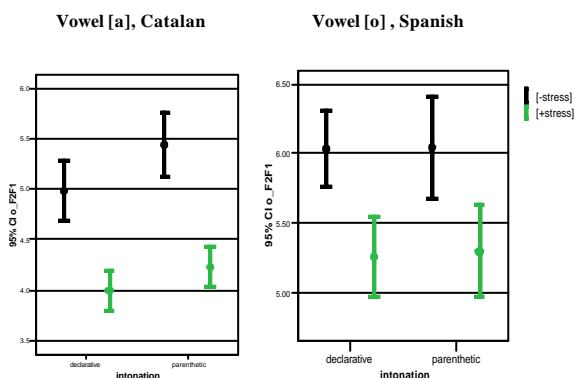


Figure 2: Mean F2-F1 difference and standard error values (in Barks) for Catalan vowel [a] (left panel) and Spanish vowel [o] (right panel) in different stress (stressed/unstressed) and intonation conditions (declarative/parenthetic).

Results from a Repeated Measures ANOVA confirmed a significant main effect of stress at  $p < .0001$  for the F2-F1 difference of the two vowels [a] and [o] in the two languages, while intonation is only significant in Catalan and the interaction 'stress\*intonation' is non-significant for either language. Therefore, like in the case of syllable duration, vowel quality cues can be interpreted as 'primary' in the stress dimension (in both accented and unaccented environments) and 'secondary' in the accent dimension. The presence of an accent does not consistently affect formant frequencies, and accented syllables have vowel qualities that are similar to those of unaccented syllables.

### 3.4. Overall Intensity

The four graphs in Figure 3 show the confidence intervals for the mean overall intensity (in dBs) for vowel [i] (left panels) and vowels [a]/[o] (right panels) in different stress and intonation conditions in the two languages. In the first place, the graphs reveal that in contrast with duration and vowel quality, there is no consistent effect of stress on overall intensity measurements (note that some contrasts show the unexpected pattern of unstressed vowels displaying higher overall intensity than their stressed counterparts). Importantly, the graphs reveal a consistent effect of accent, as vowels in declarative sentences display a higher overall intensity than those in parenthetic sentences.

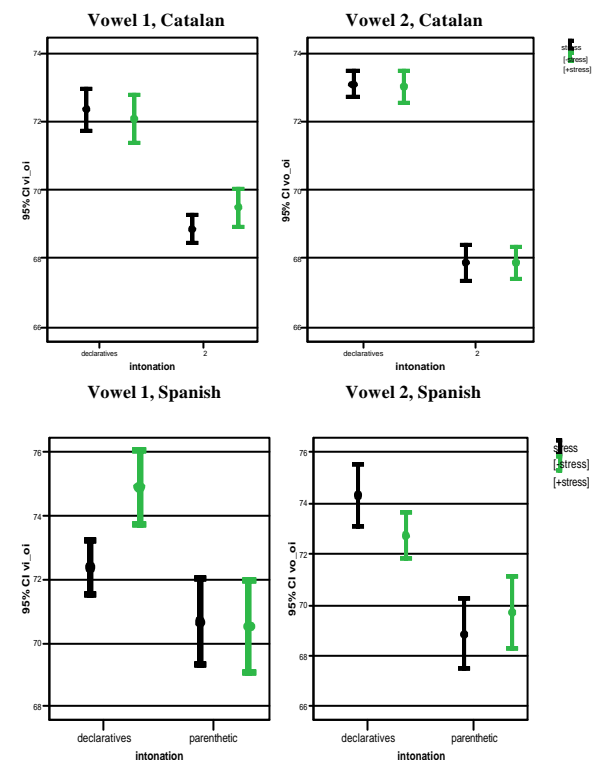


Figure 3: Mean overall intensity and standard error (in dB) for vowel [i] (left panels) and vowel [o]/[a] (right panels) in Catalan (upper panels) and in Spanish (lower panels) for different stress and intonation conditions.

Results from the Repeated-Measures ANOVA confirm a significant effect of intonation in both languages at  $p < .0001$ , while stress differences are only significant for vowel [i] in declarative sentences in Spanish. Thus, vowels in accented

environments display higher overall intensities than unaccented vowels.

### 3.5. Spectral Tilt

The two graphs in Figure 4 shows the mean spectral tilt ratios (and standard error values) for vowel [a] (Catalan) and [o] (Spanish) in different stress and intonation conditions for the two languages. First, the spectral tilt ratios of stressed vowels (in grey) are closer to 1 and show a flatter tilt than unstressed vowels (in black). Like for duration and vowel quality, this difference is maintained across intonation contexts, revealing a potential effect of stress on spectral tilt: stressed syllables tend to increase the intensity of the higher frequencies, and consequently have a ‘flatter’ spectral tilt than their unstressed counterparts. Second, the spectral tilt of vowels in accented contexts is closer to 1, and therefore the tilt decreases, in comparison to parenthetic sentences. This reveals a potential effect of the presence of an accent.

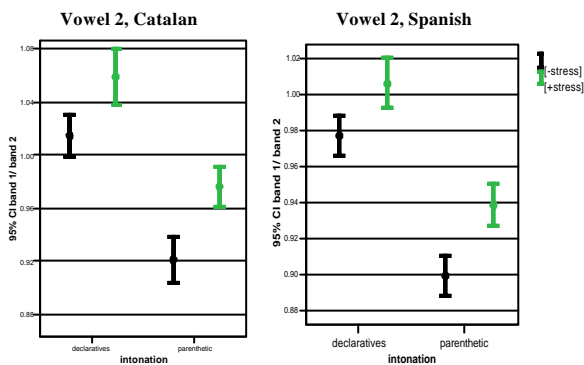


Figure 4: Mean spectral tilt ratios (and standard error values) for Catalan vowel [a] (left panel) and Spanish vowel [o] (right panel) in different stress and intonation contexts.

Results of Repeated Measures ANOVAs confirmed a significant effect of stress and intonation at  $p < .0001$  for both languages. The interaction ‘stress\*intonation’ is non-significant, confirming that the effect is maintained in unaccented contexts and enhanced in accented syllables.

### 3.6. Linear Discriminant Analyses

The contribution of each acoustic correlate to the accent/stress classification was examined by Linear Discriminant Analyses (LDA). LDA with the grouping variables of stress (+stress/-stress) and accent (+accent / -accent) were performed on measurements of duration, vowel quality, spectral tilt and overall intensity for vowel [a] (Catalan) and vowel [o] (Spanish) in order to assess the role of each variable in the prediction of both stress and accent. The Beta Coefficients in Table 2 show the relative contribution of each predictor variable to the discriminant function.

	[+stress]/ [-stress] groups				[+accent]/[-accent] groups	
	Declaratives Cat. Span.	Parenthetics Cat. Span.	Stressed Sylls Cat. Span.			
Duration	.817 .775	.721 .907	.244	.200		
Vowel Quality	-.468 -.455	-.571 -.296	-.082	-.019		
Spectral Tilt	.276 .066	.355 .262	.211	.664		

Overall Intensity	-.272 -.312	-.008 .129	.244	.337
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Table 2: Beta Coefficients of the LDA with the grouping variables of stress (+stress/-stress) and accent (+accent / -accent) on different acoustic measurements for vowels [a] (Catalan, left side of columns) and [o] (Spanish, right side).

The results of the Structure Matrices show roughly the same ranking among predictor variables across declarative and parenthetic sentences for the [+stress] / [-stress] groups in the two languages. In the case of the prediction of stressed unaccented syllables (syllables in parenthetics), it can be observed that duration is the variable with the highest absolute score, and therefore with the strongest effect, followed by vowel quality, spectral tilt, and in the last place, overall intensity, for both languages.

## 4. Conclusions

The results reported in this article confirm a clear asymmetry between the behavior of acoustic correlates of stress and accent. While syllable duration, vowel quality, and spectral tilt (intensity at high frequencies of the spectrum) are reliable acoustic correlates of the stress difference in Spanish, accentual differences are acoustically marked by intensity cues. These results therefore suggest that spectral balance is a more robust and systematic cue of stress than overall intensity, and are in keeping with previous results on other stress accent languages like Dutch or English [1], [2], [3], [4]. Importantly, our results reveal that even though Catalan and Spanish differ strongly in the use of vowel reduction to mark stressed positions, they do not differ greatly in the way they use the other acoustic correlates (duration and intensity) to signal the presence of stress and accent. Essentially, the fact that Spanish has a weak use of vowel reduction in unstressed positions does not strengthen the role of other acoustic phonetic cues in the stressed/unstressed dimension.

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