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PEAKS AND PLATEAUX: DIFFERENT F0 PATTERNS REPRESENTING THE SAME CATEGORY

Letania Ferreira[1*]

ABSTRACT: This paper revisits results of previous studies about sentence initial high tones in the Portuguese language and argues that the shape and distribution of these sentence initial pitch events in Brazilian Portuguese are more complex than previously suggested in the literature. By pointing out that peaks and plateaux are manifestations of the same pitch event the results also suggest that the peak, the highest point of a pitch excursion, is not always the main pitch target of the phrasal tone in this language. These findings contribute to the phonology-phonetics mapping in intonation.

KEY WORDS: Peaks. Plateaux. Phrasal tone.

1. INTRODUCTION

High initial (hereafter Hi) pitch events have been previously reported in Romance languages such as French (JUN and FOUGERON, 2002 and WELBY, 2003). Regarding Portuguese, Frota (1991) calls our attention to the fact that initial rises in European Portuguese (EP) show great variability of alignment as they can be aligned to the first stressed syllable of the intonational phrase, to a prestressed syllable or even to a post stressed one. While Frota (2000) proposes that the initial peak should be treated as a pitch accent, Vigário (1998) presents the peak as a phrasal tone that would signal the beginning of the intonational phrase.

In more recent work, Frota (2003) gives evidence for two types of initial peaks in EP intonation which she classifies as accentual peaks and phrasal tones. While the first type would be aligned relative to the first stressed syllable of the intonation phrase, the second type is aligned with the left-edge of the same phrase and always happens within the limits of the first prosodic word of the phrase.

Brazilian Portuguese (BP, hereafter) also presents phrase-initial rises. When describing the overall pitch contour behavior in BP Fernandes (2007) remarks that besides the pitch accent associated with the stressed syllable, this language presents "an additional H tone aligned with the second or third pretonic syllable [of a prosodic word]."

1. Assistant Professor of Linguistics, Augustana College. Rock Island, Illinois, 61201. E-mail: letaniaferreira@augustana.edu

The present study, based on Ferreira (2008), confirms the presence of Hi events in BP suggesting, however, a much more complex distribution than the one suggested by Fernandes (2007). Our study tries to replicate Frota's (2003) findings for EP in BP making a parallel between both varieties of this same language. While the literature thus far refers to the Hi pitch events in the Portuguese language as peaks, our data shows that in BP these events can be realized either by a peak or by a plateau. This finding is of crucial importance to the phonology-phonetics mapping of BP intonation as it evaluates two different F0 patterns as realizations of a single phonological category. Besides allowing us to have a better understanding of BP intonational contours, acknowledging the different shapes of Hi events in BP provides us with useful information to more efficiently model intonational contours in BP.

2. CORPUS AND EXPERIMENT

We recorded four female native speakers of BP, born and raised in the metropolitan region of Recife. At the time of the recording the speakers were 26-33 years old and three of them had completed college education while the forth subject had the equivalent of a high school diploma.

Subjects were asked to read a list of neutral declaratives three times, in the same pace they speak to friends or family members in informal situations. Subjects were not asked to repeat or imitate any kind of contour. Sentences 1 and 2 below are example of the neutral declarative sentences present on the list:

Sentence 1- **A LAma escureceu à noite** (The mud got dark at night)

Sentence 2- **Com a LAma escureceu a entrada** (With the mud s/he made the entrance dark)

Word size is an important variable in this experiment because both Frota (2003) and Fernandes (2007) suggest that words need to have more than two prestressed syllables available in order for an additional Hi pitch event to serve as an anchor at the prestressed location. Therefore, for the present experiment, the target words, underlined in the sentences above, vary from two to seven syllables and lexical word-stress is placed in a fixed position. Target words always have penultimate stress, indicated by capital letters in the sentences above. These words may be preceded either by an article or the combination of an article and a preposition.

The target word for each declarative is always placed as the first phonological word in the sentence and always followed by a verb stressed on the fourth syllable. The decision to have a fixed stress pattern surrounding the target word was made with the intent of controlling possible influences on the target contour. The data was collected in the quietest room of the building where the researcher met with each subject. Speech was sampled at 22,000 Hz. After collection, the data was manually segmented. After removing the data affected by mispronunciation or truncation, a total of 561 target words were included in the statistical analysis.

3. RESULTS

3.1. The shape

It is interesting to notice the shape variation of the F0 contour in sentence initial position. We can notice, for example, the absence of visible relevant variations on the pitch contour preceding the pitch accent (see Figure 1), as the first observable rise coincides with the stressed syllable. In the example (Figure 1 below), this syllable is /-ma/.

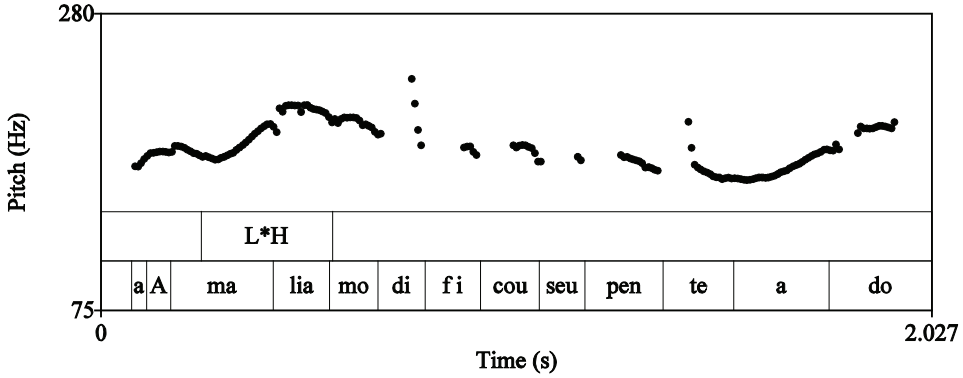


Figure 1: Pitch contour of absence Hi before first L*H

In most BP tokens, however, the data shows Hi tones preceding the first word's lexical accent, as can be seen in Figure 2 and Figure 3.

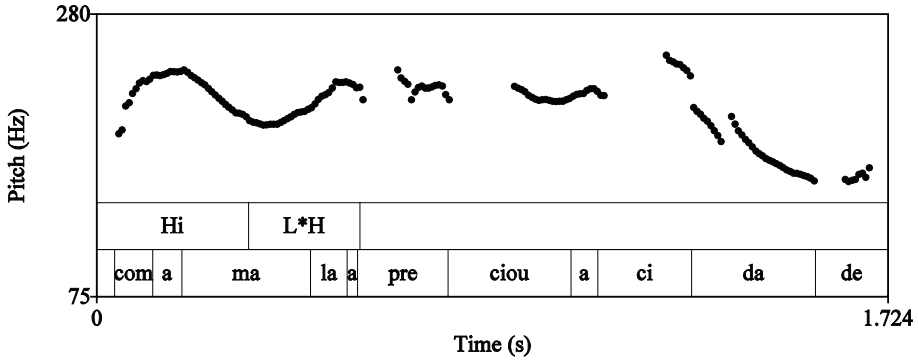


Figure 2: Pitch contour of Hi peak before first L*H

These Hi tones in some cases were shaped like peaks (see Figure 2) as they are commonly presented as a brief sinuosity. This tends to occur most frequently when the target word is a short one, compounded by 2-4 syllables. Finally, we also find cases where the first pitch accent is preceded by a plateau, as the pitch rises at the beginning of the phrase or first prosodic word and remains high for several syllables, up to the immediate pretonic (see Figure 3).

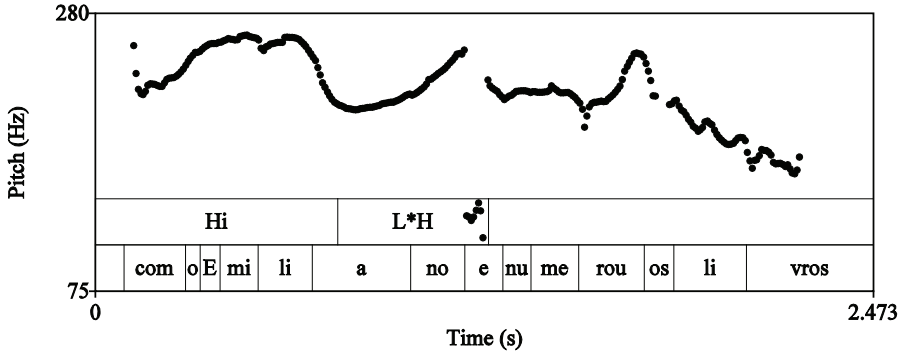


Figure 3: Pitch contour of Hi plateau before first L*H

In what concerns communicative material, it is important to remark here that the presence of a Hi preceding the first pitch accent in the declarative does not alter the meaning of a sentence. This is true for both single sinuosities, as shown in Figure 2, and plateaux, as shown in Figure 3.

3.2. Presence or absence of phrasal peaks

Hi pitch events have been phonologically analyzed in the literature in one of two ways: (i) they may be phrasal tones or, (ii) they may be part of the lexical pitch accent (FROTA, 2003; JUN and FOUGERON, 2002; WELBY, 2003). In order to identify and categorize the phrase-initial rises in this corpus, we employed the following criteria: (i) we identified the pitch accent aligned to the stressed syllable of each target word, and (ii) once the pitch accent was established, we analyzed the portion of the contour previous to the first pitch accent in order to detect the presence or absence of a relevant pitch excursion in this portion of the contour.

Measurements were taken in order to determine whether or not there was meaningful pitch event preceding the first pitch accent in each sentence. If a token presented a pitch excursion superior to 15 Hz preceding the first pitch accent in the sentence the excursion was labeled as a phrasal tone in the BP corpus. The difference in Hz was calculated from the peak to the lowest point before the following rise. The decision to have 15 Hz as a minimum value in order to call a pitch variation meaningful is based on the fact that normally F0 variations due to segmental influence are less than 15 Hz [See, for example, LEHISTE and PETERSON, 1961; HIXON, KLATT and MEAD, 1971; UMEDA, 1981).

The first Hi pitch event in a given sentence in the data can be either part of a pitch accent, either an LH or an HL, or can be independent from it. Figures 4 and 5 show the same sentence produced by the same subject in two different repetitions.

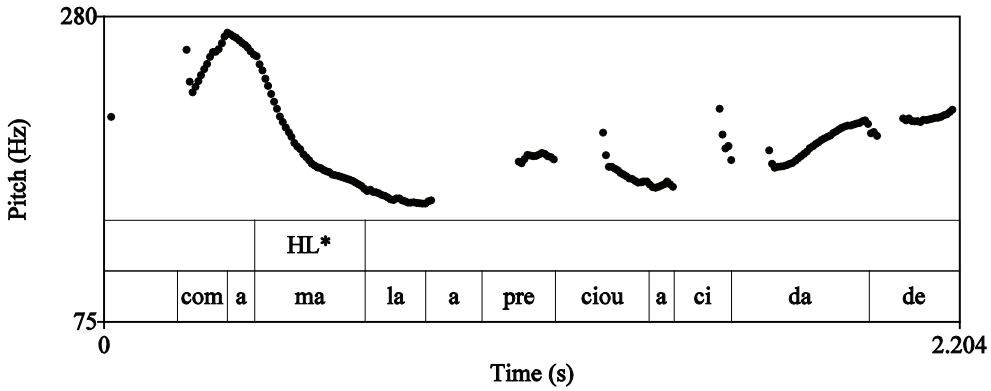


Figure 4: Pitch contour of HL* aligned to the stressed syllable /–ma/

Figure 4 shows a sentence starting by a HL pitch accent aligned to the target word and Figure 5 shows the same sentence where the first prosodic word presents a LH preceded by a Hi that is not part of the pitch accent.

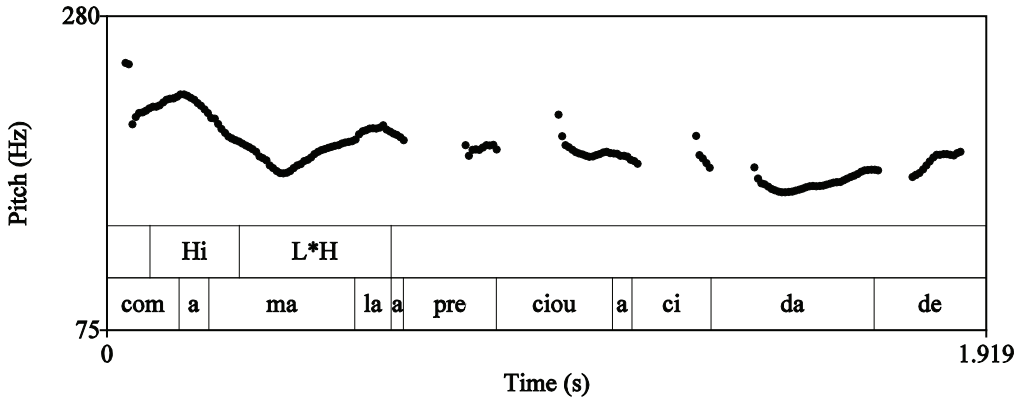


Figure 5: Pitch contour of Hi plateau before first L*H

The Hi events not related to the pitch accent, reported in the literature as phrasal tones, have been analyzed as phrasal peaks. In the next portion of this study we will try to predict the location of the phrasal peak. The peaks will be used as a reference for measurements,a standard practice used in previous work. When dealing with a plateau formation, the highest point of the plateau is marked as its peak.

3.3. Location of the phrasal peak in BP

3.3.1. Using the beginning of the word as a reference

When trying to predict the location of the phrasal peak, Frota (2003) counts the syllables starting from the left boundary of the phonological word and tries to identify to which syllable of the word the phrasal peak may be aligned. Her results show that when the phrasal peak is present, it is normally aligned to either the second or the third syllable of the first prosodic word.

Distance measurements were taken in order to try to replicate Frota's results for BP and the results indicate that in disyllabic target words the phrasal peak is placed between the article and the first syllable of the word. The data shows that, as the number of syllables in the target word increases, the peak is displaced to the right. If the word is composed of three syllables, the peak is located after the beginning of the word's first syllable. For words with four syllables, the peak occurs around the beginning of the second syllable of the word. As the number of syllables in a word increases, the peak does not continue to move towards the right. In words with five, six and seven syllables the phrasal peak is, on average, located at about the same point which is between the second and third syllables of the word.

These results partially replicate Frota's findings for EP in the present BP data. The present results are similar to Frota's findings as they show a tendency of the phrasal peak to be located around the second or third syllable of the target word in large words, words containing five to seven syllables. The results of the data analyzed in this experiment, however, differ from the results reported by Frota (2003) for EP as in the present data the phrasal peak related to short words can be located within the clitic group, fact not reported for EP and strategy that suggests different behavior of the phrasal peak in short and long words in the BP data.

3.3.2. Using the lexical stress as a reference

Also following Frota (2003), we calculate the distance between the location of the word's lexical stress and the Hi that precedes it in order to verify whether the pitch accent can serve as a reference point to predict the location of the phrasal peak.

To verify whether there is a fixed distance between the phrasal peak and the lowest point of the pitch accent that follows it, we plotted results from words that have a LH pitch accent preceded by a phrasal peak in Figure 6. To our surprise, long and short words also tend to behave differently from each other in this second type of measurement. By observing the behavior of the peak in the target words we decided to divide the total data within 2 subgroups. Words with two to four syllables are considered short words in this subdivision, while words containing five to seven syllables are placed in the long word group. See subdivision results in Figure 6:

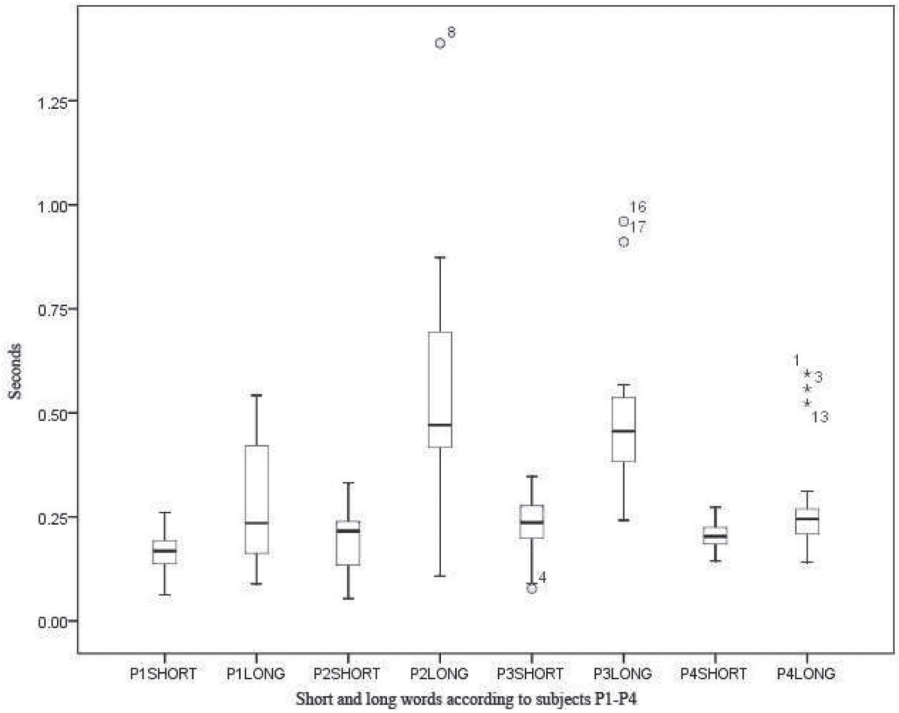


Figure 6: Distance in seconds between the phrasal peak and the L in the stressed syllable.

By comparing the left to the right plot for each one of the subjects (P1-P4), it is clear that the peak is much closer to the L target in the short words than in long words. First, for any given subject, the median line for the box plots in long words is always located higher than for short words. That implies that in shorter words the peak is normally located closer to the L target than in longer words. Second, in long words the boxes are normally larger than in short words. That indicates that the values of the distance between the peak and the following L tone are more dispersed in long words than in short ones and that the standard deviation is larger in long words. Table 1 complements the results in Figure 6 by correlating the phrasal peak and the stressed syllable:

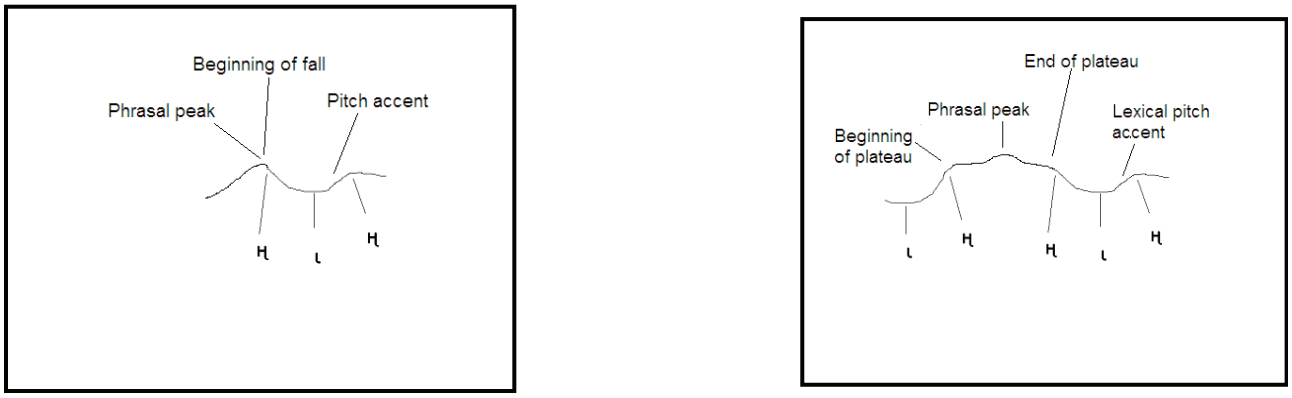
Subjects	**Words with 2-4 Syllables**		**Words with 5-7 Syllables**	
P1	0.948	0.899	0.734	0.539
P2	0.811	0.658	0.490	0.240
P3	0.832	0.693	0.610	0.372
P4	0.962	0.926	0.718	0.516
	Correlation	**R-Square**	**Correlation**	**R-Square**

Table 1: Correlation and respective R- Square of the location of the phrasal peak and the L target of the first word's lexical pitch accent to words with 2-4 syllables to the left and words with 5-7 syllables to the right.

R-square results in Table 1 show that in short words the phrasal peak is correlated to the stressed syllable 66-93% of the time, while in long words the phrasal peak is correlated to this syllable only 24-54% of the time. The individual tokens for all subjects were combined into two groups allowing us to arrive at the p-values of 4.13E-51 for the correlation in short words and 1.31E-05 in long ones. Overall, the results from Figure 6 and Table 1 show a much better correlation between the phrasal peak and the stressed syllables in short words than in long words.

4. PEAKS AND PLATEAUX

In the previous section, we showed that long and short words do not seem to behave in the same way regarding the position of the initial phrasal peak. Taking into consideration the contour shape in this data we observed that in short words the phrasal tone is commonly presented as a peak, while for longer words the phrasal tone resembles a plateau. The measurements taken in the attempt to locate the phrasal peak using both the beginning of the target word and the lexical stress as a reference, in section 3, reinforces the subdivision. Therefore, in this section we take a closer look at the pitch targets at the contour to compare them.



short words long words

Figure 7: Attempt to represent pitch target in words of different sizes in BP corpus

Figure 7 suggests that there is, indeed, a difference between words with two to four syllables and words with five to seven syllables. The first type of word presents only one pre-lexical pitch target, the phrasal peak, which coincides in location with the beginning of the fall towards the lexical pitch accent. Controversially, in the second group of words there are three different pre-lexical pitch targets: the beginning of the plateau, the phrasal peak and the end of the plateau. This last target is equivalent to the beginning of the fall towards the lexical pitch accent.

So far, all measurements taken to explain the behavior of the contours have taken the phrasal peak as reference point. Given that the phrasal peak and the beginning of the fall is the same target in short words, as illustrated in the figure above, we decided to measure the distance between both of these landmarks to the beginning of the stressed syllable to compare results. Figure 8, therefore, plots the distance from the beginning of the stressed syllable to both the beginning of the fall towards the pitch accent, labeled as FALL, and the phrasal peak, labeled PEAK. The subjects are labeled in the figure as P1, P2, P3 and P4.

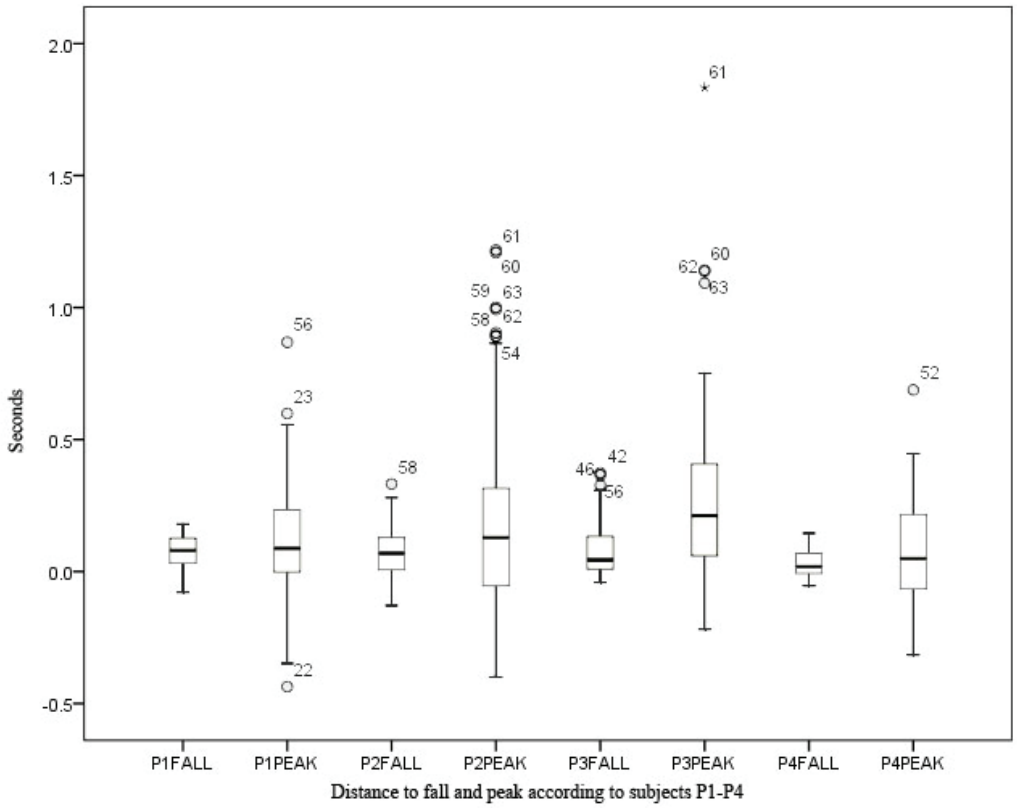


Figure 8: Illustration of the distances from the beginning of the penultimate syllable to both the "beginning of the fall" towards the next L target and to the "phrasal peak"

By comparing the left to the right plot for each one of the subjects, we see that the boxes related to the PEAK are larger; indicating that the distance between the penultimate syllable and the peak varies more than the distance from the same point to the beginning of the fall, (FALL in the figure). The smaller boxes indicate a smaller standard deviation in the data distribution.

These results suggest that, unlike previous analysis of the Hi tone in Portuguese (FROTA, 2003 and FERNANDES, 2007), the phrasal peak, highest point of the phrasal tone, is not the important target for the high initial phrasal tones in BP. On the contrary, we propose the beginning of the fall to be the relevant target with which the phrasal tone in BP is associated. According to Figure 7 the beginning of the fall coincides with the phrasal peak in short words, and in long words has been shown to be the end of the plateau. This proposal manages to unify all words of this corpus under the same analysis.

The idea of pointing out the end of the plateau as an important pitch target in the intonational contour has been proposed by House et al (1999). In their attempt to model intonation by reducing the contour to the minimum possible number of turning points, they observed possible plateau formations at the surroundings of the nuclear pitch accent in British English. They realized that when modeling the nuclear accent they obtained better results by marking two points, the beginning and the end of the plateau formation, instead of just marking the highest single point of the pitch movement, the peak. By consequence, they suggest that the end of the plateau is the real pitch target for their British English speaker and we propose that the same applies to plateaux in our data set.

Another argument against the highest point of the plateau as the main target of this pitch event is the fact that the location of the highest point within the plateau varies as the highest point of the plateau can be located at its beginning, middle or end. See Figures 9 and 10:

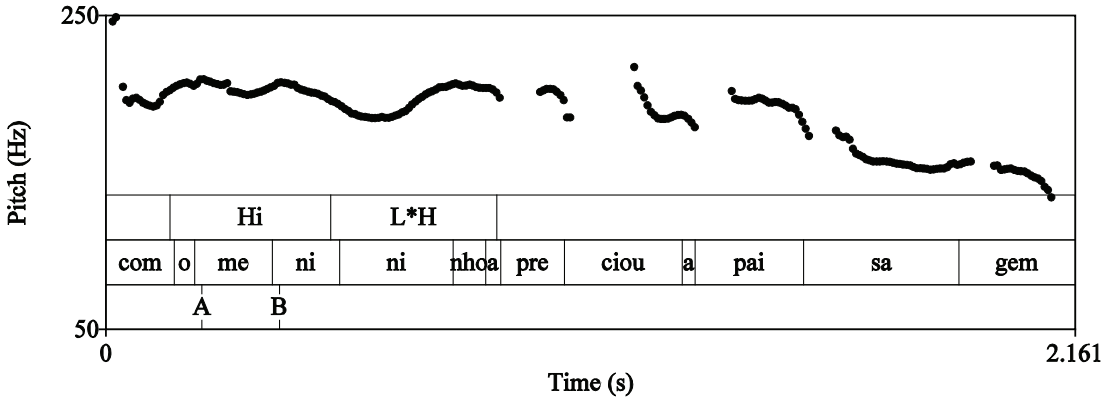


Figure 9: Pitch contour showing highest point of the plateau towards the beginning

Points A and B in Figure 9 are located within the limits of the plateau preceding the first pitch accent of the sentence. Both points illustrate values in Hz that are slightly higher than the overall plateau contour. When selecting the phrasal peak within this token we will choose point A (209.4 Hz) instead of point B (207.5 Hz) as the first one presents higher values in Hz. Point A, highest point of the plateau, in Figure 9 is located towards the beginning of the plateau while in Figure 10 this same point, is located towards the plateau's end.

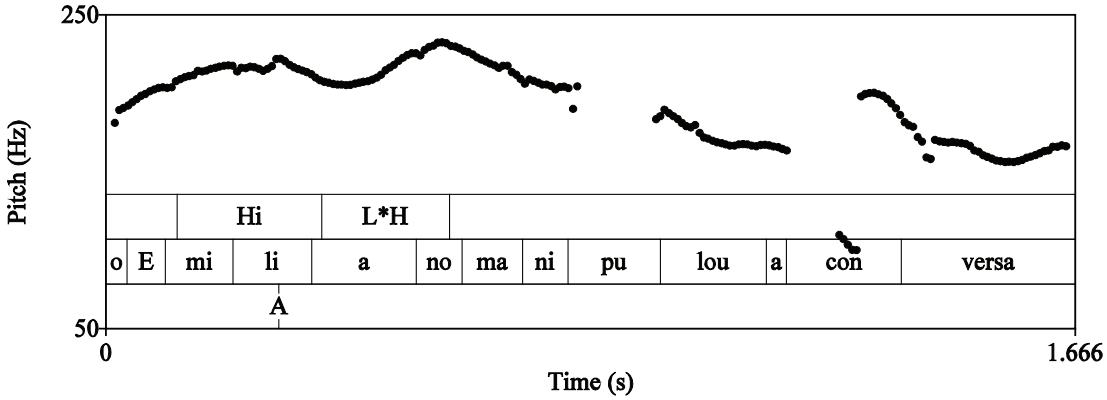


Figure 10: Pitch contour showing highest point of the plateau towards the end

Our measurements show that the difference between the highest and the lowest values within a plateau are on average only 6 Hz. Given the large variation in location of the highest point within plateau and the small variation in Hz, we, once again, question the importance of the peak, highest point of the plateau, as the pitch target of the phrasal tone in BP. We therefore argue here that instead of focusing on the highest point of a plateau, we should be asking a different question, such as: why are there plateaux on longer words?

Considering that both the peaks and the plateaux are expressions of the same pitch event, the phrasal tone, we can argue that the whole area of the plateau is of phrasal tone domain. This means that, independently of word size, the whole extension of the F0 contour preceding the first word's pitch accent can potentially be accessed by the phrasal tone in this data. As a result, our objective is to try to determine which criteria the phrasal tone follows when accessing the pre-stressed portion of the pitch contour.

We propose that a speaker raises his/her pitch by assigning an H tone to the beginning of the phrase. Once this H tone has been assigned, it spreads for as long as possible within the phrasal tone domain and just when the next target needs to be reached, (e.g. the next L tone) the action loses its effect and the pitch lowers again.

If we assume that both the peak and the plateau are two different representations of the same H phrasal tone, we can use tonal spreading to explain these two different shapes for the same pitch event. A similar case has been reported in the literature by Grice, Ladd and Arvaniti (2000) who have used the double association of phrasal tones to explain the formation of plateaux in Transylvanian Romanian. In contrast to the present study, the plateaux in Transylvanian Romanian are not located at a phrase initial position, but after the nuclear stress. Despite the location for plateau formation within the sentence, the double tone association in Transylvanian Romanian is an elegant solution that can also be proposed to BP.

Instead of assigning two different H tones to explain the pre-lexical pitch events in BP the idea of double association of the same phrasal tone to both the beginning and the end of the plateau gives the results in Figure 11. In this figure the small circles stand for the different syllables of a target word. Words from two to seven syllables are represented in the figure, and the illustration of double tonal association has been represented only for some of these words but would work the same way for all of them.

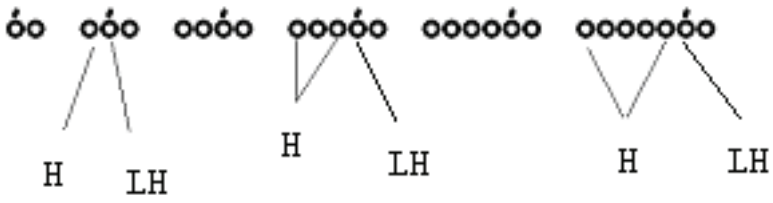


Figure 11: Illustration of double association of phrasal peak

In Figure 11, consider, for example, words with three syllables in contrast with five syllable words. According to the figure, the phrasal tone is associated with the beginning as well as with the pre-stressed syllables of each word. In trisyllabic words the beginning of the word is at pre-stressed syllable position. Therefore, one should expect a peak and not a plateau, given the instantaneous rise followed by the immediate fall within the same syllable in order to meet the next L target at the stressed syllable.

On the other hand, in words with five syllables the association of the H phrasal tone is sustained for an interval of three syllables, from the beginning of the word until the pre-stressed syllable. Only at the beginning of the stressed syllable does a fall take place to accommodate the L of the word's pitch accent, and as a result, a plateau is formed for the interval during which the phrasal tone is high. In summary, Figure 11 perfectly represents the difference between peaks and plateaux in the BP data with the simple use of double tonal association. This explains the behavior of short and long works in this data under a unified strategy.

5. DISCUSSION AND CONCLUSION

In this paper we show that, as previously claimed by the literature for Portuguese, Hi tones can precede and be part of pitch accents. This coincides with findings for EP and BP by Frota (2003) and Fernandes (2007) respectively. The data analysis shows no difference between tokens starting by a preposition and the ones starting by an article. The results from the data analyzed in this study show that in BP the phrasal tone can either present itself in the form of a peak or a plateau. The results also suggest that the peak, the highest point of the plateau, is not the main pitch target of the phrasal tone. In this study, we tried to predict the location of the phrasal peak based on the same two different landmarks used by Frota (2003), the lexical stress and the beginning of the word, but the outcome for both trials was not convincing.

Insisting on using the phrasal peak as the main pitch target of the phrasal tones in this corpus resulted in a dichotomy between long and short words. Conversely, by ignoring the phrasal peak and focusing on other targets such as the end of the plateau it is possible to verify that phrasal tone behaves uniformly in BP neutral declaratives independently of word size. For that reason we claim that understanding the exact location of the peak is not necessarily relevant in order to understand the behavior of initial phrasal tones in neutral declaratives in BP.

In order to achieve an invariable explanation that fits all word sizes in this data, it was necessary to argue that the phrasal tones are by default simultaneously double associated with the first syllable of the first prosodic word and with the beginning of the prestressed syllable of this same first prosodic word. In cases when these targets are not available for association for some reason, optional neighboring targets, such the article in disyllabic words, are used for tonal association.

By unifying the explanation of the whole BP data set using the notion of double association, it is possible to argue that in BP the initial peaks and plateaux are not two different types of pitch events. On the contrary, based on the idea of double association, the peaks and the plateaux in BP initial neutral declaratives are two manifestations of the same pitch event, the phrasal tone. These results are an important step to the phonology-phonetics mapping of intonation in BP as they show us two different F0 patterns analyzed as realizations of a single phonological category. Among the implication for these findings we can highlight that recognizing the existence of plateaux in BP sentence initial position, as well as understanding that the peak is not always the most important pitch target in this kind of intonation contour, will help us to more efficiently model intonation in this language.

PICOS E PLATÔS: DIFERENTES PADRÕES DE F0 REPRESENTANDO A MESMA CATEGORIA

RESUMO: Este artigo revisita estudos anteriores sobre os tons altos em posição inicial de enunciado na língua portuguesa e defende que o contorno entoacional e a distribuição desses eventos tonais no português brasileiro são mais complexos do que foi sugerido anteriormente pela literatura. Ao indicar que picos e platôs são diferentes manifestações do mesmo evento entoacional, os resultados desse estudo também sugerem que o pico, ponto mais alto do *pitch accent*, nem sempre é o ponto principal do *pitch accent* nos *phrasal tones* dessa língua. Esses resultados contribuem para o mapeamento fonologia-fonética na entoação.

PALAVRAS-CHAVE: Picos. Platôs. *Phrasal tones*.

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