Tonal association and target alignment in European Portuguese nuclear falls

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Intonational phonology analyses of nuclear falls often treat the tones that make up falling contours either as separate tonal events, i.e. as a single-tone pitch accent and an edge tone of some sort, or as part of a bitonal accent. This work evaluates the competing phonological analyses for the broad and narrow focus nuclear falls in European Portuguese declaratives. By exploring the factors that may affect the alignment of the H(igh) and L(ow) targets, such as proximity to prosodic edges and distance between word stresses, evidence is presented in support of the bitonal hypothesis for both the neutral and the focus falls. Subsequently, the relation between the H and L targets is shown to differ in the two bitonal accents, supporting a leading/trailing tone distinction whereby the leading tone is timed independently of the T* and the trailing tone is timed with reference to the T*. Besides bringing phonetic data to bear on the phonological organisation of pitch contours, the results have consequences for the view of intonation primes as tonal targets (rather than configurations) and bitonal accents as structured (rather than flat) tonal units.

1. Introduction

Intonational phonology analyses of nuclear falls in various languages have disagreed on the organisation of the tones that make up such contours. The main point of dispute is between the proposal to capture the falling movement by means of separate tonal events and the proposal of a bitonal accent of the H+L type: the former position has been maintained by Pierrehumbert 1980 for English, Benzmüller & Grice 1998 for German, D'Imperio 1999 for Neapolitan Italian, Grφnnum & Viana 1999 for European Portuguese; the latter has been supported by Ladd 1983 and Gussenhoven 1984 for English, Grabe 1997 for German, D'Imperio & House 1997 for Neapolitan Italian, Frota 1997 for European Portuguese. The issue is naturally intertwined with the typology of pitch accents and edge tones assumed in the different accounts, as well as with their phonetic interpretation.

This paper investigates the f_0 contours of nuclear falls in European Portuguese declarative sentences with a broad focus or a narrow focus reading. The analysis of the falling patterns developed here follows the auto-segmental metrical theory of intonational phonology, according to which intonation has a phonological organisation, and intonational features relate with independent features of the phonological organisation of speech established on the basis of prosodic structure (Beckman & Pierrehumbert 1986, Pierrehumbert & Beckman 1988, Hayes & Lahiri 1991, Grice 1995*a*,*b*, Prieto, van Santen & Hirschberg 1995, Jun 1996, Ladd 1996, D'Imperio 1996, Hirschberg & Avesani 1997, Arvaniti, Ladd & Mennen 1998, 2000, Sosa 1999, Gussenhoven & van der Vliet 1999, Grice, Ladd & Arvaniti 2000, among others).

One of the basic assumptions of the approach to intonation followed here is the view that the intonation contour is formed by a string of tones. In languages like English and European Portuguese, the events of the tonal string are either pitch accents (T*) or edge-related tones. The former are tonal events associated with prominent elements in the segmental string. The latter are tonal events linked to prosodic domain edges. Edge-related tones comprise two categories, boundary tones and phrase accents (respectively, T% and T^- in Pierrehumbert's notation). Between the local tonal events, the intonation contour is phonologically unspecified.

In languages such as Bengali and European Portuguese (see, respectively, Hayes & Lahiri 1991 and Frota 2000), the prosodic structure relevant to intonation is that provided under the Prosodic Hierarchy Theory, as developed in Selkirk (1984), Nespor & Vogel (1986), and Hayes (1989), among others. The phonological phrase (ϕ) and the intonational phrase (I) will thus be the prosodic constituents used in the description of European Portuguese intonation structure that follows.

1.1. Nuclear falls in European Portuguese declaratives

There are two indisputable facts that come out of the literature on European Portuguese declarative intonation: first, the declarative contour consists of an initial rise and a sharp final fall, between which there is a plateau; secondly, the falling movement occurs in the last stressed syllable of the intonational phrase (Delgado Martins & Lacerda 1977, Martins 1986, Viana 1987, Frota 1991, 1993, Falé 1995, Vigário 1998, Grϕnnum & Viana 1999). Both the sparseness of tonal events and the nuclear fall that characterise neutral declaratives are illustrated in Figures 1-2 (panel A).

FIGURES 1 & 2

This contour is typical of sentences uttered out-of-the-blue or in response to 'what-happened' questions, that is sentences with a broad focus reading. In addition, the same type of nuclear fall has also been found in the pitch contour of topicalised phrases (*in situ* or dislocated phrases that express what the sentence is about - Frota 2000).

Despite the coincident phonetic descriptions, different authors have proposed different analyses of the falling movement. In Viana (1987), it is accounted for by a H* L tonal sequence associated with the final stressed syllable (the nature of the L is not discussed by the author). In the analyses of Frota (1993, 1997), Falé (1995) and Vigário (1998), on the other hand, a bitonal pitch accent involving a High and Low tone (H+L*) is assumed. Finally, in Grϕnnum & Viana (1999) the neutral declarative fall is analysed as comprising a L* accent preceded by a tonal target explained by a prior H* tone.

The neutral declarative (and the topic) contour can be compared with the contours of sentences in which a particular constituent is focalised, and thus the broad focus reading is lost in favour of a narrow/contrastive focus reading. Although the literature on focus intonation is much more limited than that on its neutral counterpart, there are two salient properties in the available descriptions: a falling pitch movement is present in the vicinity of the stressed syllable of the focalised element, regardless of its position in the intonational phrase; if the syllable bearing the focus nuclear fall is neither the last stressed syllable of the intonational phrase nor adjacent to the last stressed syllable, a post-focal fall occurs in the final stressed syllable (Frota 1997, 2000, Vigário 1998). Figures 1-2 (panel B) and Figure 3 illustrate these properties.

FIGURE 3

The focus falling movement looks different from the neutral one. This difference is reflected in the analyses of the focus nuclear fall, which have all assumed a bitonal pitch accent (H*+L). This proposal, however, has never been systematically confronted with alternative analyses of nuclear falls, such as those proposed for Bengali or German (Hayes & Lahiri 1991, and Benzmüller & Grice 1998, respectively).

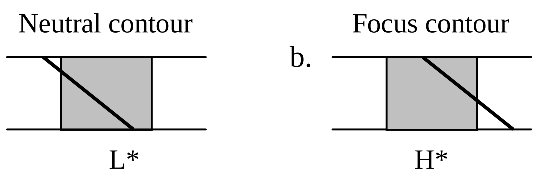
It should be noted that in all the previous descriptions of both the neutral nuclear fall and the focus nuclear fall a HL melody is involved. The assumption that there are two targets in both pitch contours is not surprising. In neither case can the L target be described as a consequence of "sagging" interpolation between two H targets: in the neutral fall, there is no succeeding H; in the focus fall, a following H (pronounced with a low peak) may, but need not appear in the contour (Figures 1-2B and Figure 3). Perhaps more importantly, the transitions between H targets in European Portuguese, such as the prenuclear plateau mentioned above, have been successfully described by means of straight-lines (Viana 1987, Frota 1991, Grϕnnum & Viana 1999). Unlike English (Pierrehumbert 1980), but similarly to Swedish or Japanese (Bruce 1977, Pierrehumbert & Beckman 1988), European Portuguese seems not to show sagging transitions.

In accordance with the previous literature, we will consider that the nuclear falls involve a HL melody. Contrary to the prior analyses, however, this paper explores the alternative phonological treatments of the two HL tonal sequences.

1.2. The phonological status of nuclear falls

On the basis of the earlier descriptions, it is clear that the two falling contours differ in the location of the peak relative to the stressed syllable. In the neutral contour, the peak precedes the stressed syllable, whereas in the focus contour it coincides in time with the stressed syllable. This difference is depicted in (1), where the box indicates the domain of the stressed syllable (see also Figures 1-3 above).

(1) a. b.



It can thus be hypothesised that the neutral fall includes a starred low tone, while the focus fall includes a starred high tone. Similar timing contrasts involving peaks have been found in other languages and have been argued to express different lexical or semantic-discourse meanings (e.g. HL contrast in Swedish word accents, Bruce 1977; LH contrasts in English, Pierrehumbert & Steele 1989; LH/HL contrasts in Neapolitan Italian, D'Imperio & House 1997 and D'Imperio 1999; accent-lending falls in Dutch, Verhoeven 1994, Caspers 1999).

As to the status of the unstarred tones and the relationship between the two tones in each of the HL sequences, the possible alternatives are listed in (2)-(4).

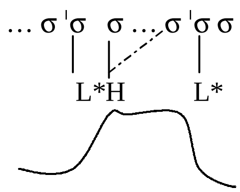
(2) *The neutral HL sequence*

a. Edge tone and monotonal accent

(i.e. a word or ϕ-initial tone, realised in the first syllable of the relevant domain, followed by a T*)

[[σ ˈσ σ]ω …]ϕ
| |
H   L*

b. Preaccentual target explained by a preceding accent via spreading



(Ladd 1983,Grice 1995*b*, for English)

c. Complex pitch accent

Ex: declaratives in Italian, H+L* (Grice 1995*a*, D'Imperio 1996, Hirschberg & Avesani 1997)

(3) *The focus HL sequence*

a. Monotonal accent and boundary tone

Ex: focus in Bengali, L* Hp (Hayes & Lahiri 1991)

b. Monotonal accent and phrase accent

Ex: Wh-questions in Greek, H* L^{-} (Grice *et al.* 2000)

c. Complex pitch accent

Ex: focus in Palermo It. , H*+L;
yes-no questions in Palermo and Neap.It., L*+H (Grice 1995*a*, D'Imperio 1999)

In the phonological representations hypothesised in (2a-b) and (3a-b), the falling movement is conceived as a transition between two independent tonal events. The representations hypothesised in (2c) and (3c), by contrast, treat the fall as a bitonal pitch accent.

If the testing of the hypotheses in (2) and (3), turns out to support one or both of the bitonal representations, then the hypotheses in (4) about the phonology and phonetics of bitonal accents will also have to be examined.

(4) *T+T*

a. Both leading T and trailing T are timed with reference to T*
(a head-initial/head-final difference, as in Pierrehumbert & Beckman 1988)

b. Only trailing T is timed with reference to T*
(a leading/trailing tone difference, as in Grice 1995*b*)

c. Neither leading T nor trailing T is timed with reference to T*
(independent targets, aligned with reference to some segmental landmark)

Ex: prenuclear rises in Greek (L H)

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… V C ˈV C V …
     |         |
     L         H
```
(Arvaniti *et al.* 2000)

In the framework of intonation analysis adopted here, the choice among the alternatives in (2)-(4) should be empirically based. It is thus crucial to look for phonetic criteria to decide which is the starred tone and determine the relationship between the tones in each of the HL sequences. If target alignment is a reflection of phonological association, as generally assumed in the intonational phonology approach (e.g. Pierrehumbert & Beckman 1988, Pierrehumbert & Steele 1989, Hayes & Lahiri 1991, Grice 1995*a*, Arvaniti *et al.* 1998, Benzmüller & Grice 1998, Grice *et al.* 2000), then the following is expected: tonal anchoring relative to (i) a prominent element indicates a T*, while tonal anchoring relative to (ii) a prosodic edge indicates a boundary tone. Furthermore, tonal anchoring conditioned by both (i) and (ii) indicates a phrase accent. Although not all phrase accents necessarily show these properties, this kind of tonal event has been described as combining a phonological edge affiliation with a secondary association to a stressed syllable in many cases (Ladd 1996:chap.6, Grice *et al.* 2000). In regard to bitonal pitch accents, the duration and slope properties of the accent are expected to indicate the kind of relationship that holds between the two tones (Arvaniti *et al.* 1998, D'Imperio 1999).

In what follows, phonetic data will be examined in the light of the hypotheses in (2)-(4). We will present evidence in support of one of the competing phonological analyses for the European Portuguese nuclear falls. Implications of the results for the tonal targets view and the status of unstarred tones in intonational phonology will be subsequently discussed.

2. Methods

2.1. Speech materials

Read speech materials were designed to contain pairs of tokens with the same segmental string and the different nuclear falls in the same position, or the same type of nuclear fall in different positions. These were obtained by setting up a felicitous context (by means of a previous paragraph/question - see example (5e) below) that would elicit a neutral reading, a topic reading, or a focus reading. As the two nuclear falls had been shown to express different meanings (Vigário 1998, Frota 2000), it was expected that the neutral contour would be produced in the case of the neutral and topic readings, and the focus contour in the case of the focus reading. This is illustrated in (5) (capitals signal the nuclear accented syllable; the focused constituent is in bold; expected intonational phrasing is indicated).

(5) Example from Dataset 1
As angolanas ofereceram especiarias aos jornalistas
'The Angolans gave spices to the journalists'

a. [As angolanas ofereceram especiarias aos jornaLIStas]I (neutral reading)
neutral contour

b. [As angolanas ofereceram especiarias]I [aos jornaLIStas]I (topic reading)
neutral contour

c. [As angolanas ofereceram especiarias **aos jornaLIStas**]I (focus reading)
focus contour

d. [As angoLAnas]I [ofereceram especiarias aos jornalistas]I (topic reading)
neutral contour

e. Context: Sabe-se que os jornalistas receberam especiarias: quem lhas ofereceu?
'It is known that spices were given to the journalists: who gave them?'
[**As angoLAnas** ofereceram especiarias aos jornalistas]I (focus reading)
focus contour

In the corpus, the distance of the nuclear accented syllable from and to various prosodic edges, and the number of postnuclear syllables before the next word stress varied. The nuclear accented syllable was preceded by between zero and three prenuclear syllables up to the left-edge of the nuclear word (ω), and by between two and five syllables up to the left-edge of the phonological phrase (ϕ) that contains the nuclear word. The distance in syllables to the right-edge of ω and ϕ varies, respectively, from zero to two and zero to three postnuclear syllables. Finally, the interval between the nuclear accented syllable and the next word stress may consist of zero to three syllables. Examples of the different conditions are provided in (6)-(7), with indication of prosodic phrasing (the postnuclear word stress is underlined).

(6) Example from Dataset 2

a. [[O galã]ϕ [anda]ϕ [de PORsche]ϕ]I (neutral contour)
b. [[**O gaLÃ**]ϕ [<u>an</u>da]ϕ [de porsche]ϕ]I (focus contour)
c. [[**O gaLÃ**]ϕ [an<u>da</u>va]ϕ [de porsche]ϕ]I (focus contour)
'The romantic lead drives/used to drive a Porsche'

(7) Example from Dataset 2

a. [[O pintor]ϕ [retratou]ϕ [uma manhã angeliCAL]ϕ]I (neutral contour)
b. [[O pintor]ϕ [retratou]ϕ [uma **maNHÃ** angeli<u>cal</u>]ϕ]I (focus contour)
c. [[O pintor]ϕ [retratou]ϕ [uma **maNHÃ** <u>âm</u>bar]ϕ]I (focus contour)
'The artist painted an amber/angelic morning'

Due to the need to obtain specific prosodic configurations, such as the ones in (5)-(7) above, a number of additional factors had to be controlled for in the corpus: syntactic structure, constituent weight, and the presence of contexts for the application of prosodically conditioned sandhi rules and rhythmic processes. Within the limits of these constraining factors, an effort was made to choose words with sonorants in the intonationally relevant syllables and sentences that were natural sounding. The materials illustrated in (5) and (6-7) will be respectively referred to as Dataset 1 and Dataset 2.

All the materials are related to the hypothesis that there is a L* in the neutral contour and a H* in the focus contour (see (1) above). The examination of the alignment of the low target in the neutral fall and the high target in the focus fall should provide an answer as to the starred status of the L and H tones, respectively.

Materials such as those illustrated in (6)-(7) allow the testing of the hypotheses put forward in (2) and (3) regarding the status of the unstarred tones. To examine the alternative analyses of the nuclear falls, we are interested in the effects on the alignment of the HL targets of both the distance relative to prosodic edges and the next word stress. Specifically, if the contours involve an edge tone (hypotheses 2a-3a), it is predicted that target alignment should be affected by the distance relative to a given prosodic edge. If target alignment shows dual behaviour in that it is both constrained by a prosodic edge and a stressed syllable, this would constitute evidence for the phrase accent analysis (hypothesis 3b). If the presence of a preceding accent turns out to be is crucial for deriving the alignment of a specific target, this would support the spreading account (hypothesis 2b). Finally, the complex pitch accent analysis (hypotheses 2c-3c) predicts that the alignment of the HL targets should show a strict relationship between the two tones, irrespective of the factors mentioned above.

The alternatives in (4) can be assessed by means of materials such as those in (5). These materials allow a direct comparison between the two falling contours produced in exactly the same segmental string. If one of the targets is timed with reference to the other in both HL sequences (hypothesis 4a), then a constant duration of the interval between targets and/or a constant slope is expected to characterise both nuclear falls. Conversely, the absence of any timing dependence between targets in either case (hypothesis 4c) would predict the opposite result. If such timing dependence is a property of only one of the sequences (hypothesis 4b), a contrast in the timing relation between targets and in the slope values is expected to set the two nuclear falls apart.

2.2. Procedure

A total of 15 test-sentences (9 from set 1 and 6 from set 2) were randomly included in a larger corpus of sentences, which contained three repetitions of each test-sentence. The materials were recorded by three female native speakers of European Portuguese (Lisbon variety). A total of 135 utterances (15 test-sentences x 3 repetitions x 3 speakers) were produced.

The speakers, all graduate students at the University of Lisbon at the time of the recordings, were instructed to read the sentences as naturally as possible in response to a previously given context. They were free to repeat the sentences in case they considered their reading not fluent or unnatural. The three best repetitions of each sentence were included in the data, with two exceptions: one of the speakers did not produce the intended nuclear fall in two of the three repetitions of one sentence, and thus this sentence was not considered for this speaker; for three other test-sentences, four repetitions of each sentence by one speaker were found to be equally acceptable and were all included in the data.

The recordings were made on audiotape in the phonetics room of the Centre of Linguistics of the University of Lisbon. The materials were later digitised at 16kHz, using the Sensimetrics Speech Station package for speech analysis. In the f_0 contours plotted using the pitch tracker facility of the Speech Station, the location of the targets involved in each nuclear fall was labelled. Identification of the H and L targets was according to the following criteria: the H was defined as the *local maximum* in the vicinity of the stressed syllable immediately before the fall (this includes both the end of a sequence uttered at the same pitch (not precluding declination) and the highest point of locally higher pitch); the L was defined as the *local minimum* also in the vicinity of the stressed syllable right before the ensuing low stretch. Examples of target identification are provided in Figure 4.

FIGURE 4

While the identification of the H was unproblematic, in some cases the L target was difficult to locate consistently. In such cases, a decision was made with the help of the Pitch ASCII facility of the Speech Station, that produces a text file with every f_0 value. This file can then be edited and used to plot a contour where regression lines are fitted to the falling region and to the low stretch after the fall. The point where the two lines intersect is taken to define the L target (a similar methodology to find a low has been used by Pierrehumbert & Beckman 1988 and D'Imperio 1996).

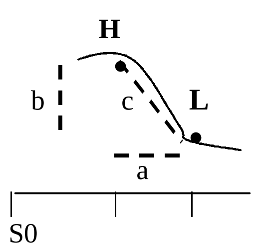
Two locations in the segmental string were marked with the help of zoomed waveforms in combination with spectrograms: the onset of the nuclear accented syllable (S0) and the offset of the nuclear vowel (V1). Standard criteria of segmentation were followed (Peterson & Lehiste 1960). However, the segmentation of the vowel-vowel sequences found in the materials (see the examples in (6-7) above) requires some comment, due to its inherent difficulty. In these cases, energy curves were also used in addition to waveforms and spectrograms. The fluctuations in the location of V1 that could result from segmentation difficulties were assessed on a sample of 15 cases that were segmented three times (each time in different orders, and on different days). The results showed an average fluctuation of 5.23 ms, which did not undermine the judgements of target location as preceding or following V1.

2.3. Measurements

The data was first examined for syllable alignment. Information on the location of the targets inside or outside the nuclear syllable domain was obtained. The alignment of the targets not located within the nuclear syllable was expressed in number of syllables from the nuclear syllable (-1, -2, -N for prenuclear syllables and +1, +2, +N for postnuclear syllables). This observation of syllable alignment provided a primary test to the hypotheses in (1), (2) and (3), as it scrutinises the timing of the tonal targets with respect to the nuclear syllable, and the effects of both the distance from prosodic edges and a following word stress.

Additionally, several timing and f_0 measurements were obtained. They are schematically indicated in (8): the duration of the distance between S0 and the H and L targets (HtoS0 and LtoS0, respectively); the duration of the interval between H and L (DHL); the f_0 difference between H and L (f_0HL); the slope of the falling contour, measured as the relation between f_0HL and DHL.

(8)



(a) DHL
(b) f_0HL
(c) Slope=f_0HL/DHL

HtoS0, LtoS0

In the materials where the two nuclear falls occur at the same position in the segmental string (see the examples in (5) above), a further measurement was considered: the duration of the distance between V1 and the L target (LtoV1).

The measurements HtoS0 and LtoV1 bear on the starred status of the H and L tones hypothesised in (1). DHL, slope, and the relation between HtoS0 and LtoS0 are particularly helpful in investigating the different alignment effects predicted by the competing hypotheses in (3), especially those related to the phrase accent analysis which may be more subtle and thus harder to disclose.

In case the data support the bitonal accent hypothesis in either the neutral contour or the focus contour, or both, the alternatives put forward in (4) require examination. The relations between DHL and f_0HL, on the one hand, and HtoS0 and LtoS0, on the other, should provide the answer: a correlation between DHL and f_0HL, indicates a tendency towards a constant slope of the fall; a correlation between HtoS0 and LtoS0 indicates a tendency towards a constant duration of the interval between targets; the absence of such correlations indicates the absence of any timing dependence between targets.

3. Results

3.1. Evidence for the starred tone

Table I shows the position of the H and L targets relative to the nuclear syllable. The contrast between the two contours is clear. In the neutral contour, the peak precedes the nuclear syllable in 83% of the cases contra zero occurrences in the focus contour. Conversely, the low always aligns with the nuclear syllable in the neutral contour and never occurs in this position in the focus contour. These results support hypothesis (1), according to which L is a starred tone in the neutral fall, while H is a starred tone in the focus fall.

TABLE I

However, the peak may also occur one syllable after the syllable it is typically aligned with in both contours. In the neutral fall this pattern of alignment characterises the topic sentences where the peak is I-initial (like (5d) above), as can be seen in Figure 5. In the focus fall the initial position of the peak (as in (5e) and 6(b-c)) also accounts for the cases of peak displacement. Similar cases of late alignment of the first peak in the utterance have been described for European Portuguese in Vigário (1998), Grϕnnum & Viana (1999) and Frota (2000), and parallel a tendency for late peak placement found in other languages (e.g. Silverman & Pierrehumbert 1990, Prieto *et al.* 1995, Wichman, House & Rietveld 1997).

FIGURE 5

It should be further noticed that peak displacement has different consequences for the alignment of the L target in the two contours (Table I). In the neutral fall, the L aligns with the nuclear syllable whether the peak has been displaced or not; in the focus fall, peak displacement is largely coincident with later alignment of the following L as well (35% of late peaks and 37% of late lows). Again, this is consistent with the starred status of the low in the neutral contour, but not in the focus contour. Overall, the syllable alignment results clearly set the two nuclear falls apart, as illustrated in Figure 5.

3.2. The neutral contour

The results in Table I also bear on the hypothesis put forward in (2a) regarding the status of the peak in the neutral fall. If the peak were an edge tone as hypothesised in (2a), its location in the prenuclear string relative to the nuclear syllable should vary. However, it was found that the peak typically occurs within the prenuclear syllable, irrespective of the distance of the nuclear syllable from the left-edge of ω (0 to 3 syllables) or ϕ (2 to 5 syllables). The results thus failed to support hypothesis (2a). This finding is confirmed by the alignment patterns of the neutral fall described in Grϕnnum & Viana (1999), according to which the peak is aligned just before the nuclear accented syllable and never before the prenuclear syllable.

As to the hypothesis that the peak derives from a preceding pitch accent (2b), it can be straightforwardly dismissed on the basis of the occurrence of the neutral contour in one-word intonational phrases, that is in strings where the only accentable syllable is the nuclear one. Figure 2(A) illustrates one of such cases.

Contrary to the edge-tone or prior accent analyses, the bitonal hypothesis in (2c) is confirmed by the data. The peak closely precedes the low, whether located in the prenuclear or the nuclear syllable (Table I and Figure 5), as expected from a leading H tone of a bitonal H+L* accent.

3.3. The focus contour

Unlike in the neutral fall, the syllable alignment results of the focus fall show more variation in the position of the unstarred tone in the postnuclear string (Table I). Although the location of the L target one or two syllables after the nuclear one is apparently related with the absence or presence of peak displacement (section 3.1), this variation may also be consistent with the alignment effects predicted by the hypotheses in (3a) and (3b).

According to hypothesis (3a), the alignment of the low should be affected by the distance to a following prosodic edge. The results in Table II, however, show that proximity to the nuclear syllable preponderates over proximity to the prosodic edge: on the one hand, the +2 alignment is not driven by proximity to the prosodic edge, as it may occur whether the second postnuclear syllable is or is not adjacent to a prosodic boundary; on the other hand, the +1 alignment dominates even when the location of the L in the second postnuclear syllable would make it closer to a prosodic boundary.[1] Hypothesis (3a) is thus not supported by the data.

TABLE II

The phrase accent hypothesis in (3b) predicts a composite set of alignment effects. If the phrase accent is simply characterised by a phonological edge affiliation (as in Cypriot Greek question intonation - Grice *et al.* 2000), the kind of effect expected would be the same as that described in the previous paragraph, which was already shown not to hold. If the phrase accent combines the former property with stress-seeking properties (as in German nuclear falls - Benzmüller & Grice 1998), then the alignment of the low should be affected by the distance to a following word stress. Before examining whether this kind of effect is present in the data, a clarifying remark is needed regarding stress clashes in European Portuguese. As mentioned in section 1.1, European Portuguese is characterised by a sparse distribution of pitch accents whereby only the first stressed syllable and the nuclear stressed syllable of an intonational phrase are pitch accented in the typical case. Thus, a stress clash in this language does not induce the tonal crowding situation characteristic of adjacent accented syllables, which is known to affect the behaviour of tonal targets (e.g. Arvaniti *et al.* 1998). As a result, the behaviour of targets in stress clash sequences is not different from the cases where two or more syllables intervene between word stresses (Frota 2000:chap.3).

Table III presents the syllable alignment results of the interstress interval effect. It can be seen that contrary to expectations the occurrence of +2 alignment does not increase with the size of the interstress interval.

TABLE III

Although these results do not support hypothesis (3b), it may well be the case that the stress-seeking effects have remained undisclosed by an examination based on syllable counts. Grice *et al.* (2000) suggest that these effects may be rather subtle and require detailed instrumental research. The testing of hypothesis (3b) was thus pursued by examining how the interstress interval affects the variation of the DHL and slope values in Dataset 2, where the distance between stresses ranges from zero to two syllables. It was expected that larger intervals yield longer DHLs and shallower slopes.

DHL values for the different interval sizes are shown in Figure 6. It can be seen that the distance between targets either remained unaffected (this is the dominant pattern), or was affected in conflicting ways contrary to our predictions (for MV it decreases when the interval gets larger, in the 'galã' subset; for CF it increases with the interval, in the 'manhã' subset).

FIGURE 6

These data were tested through a two-way ANOVA on pooled data for all speakers, with SPEAKER and INTERVAL SIZE as factors. The latter variable had two levels in each of the two subsets of data analysed: 0,1 for 'galã', and 0,2 for 'manhã' (the two subsets were illustrated in (6) and (7), respectively; in all the analyses performed, the results that yield $p \leq .01$ are considered statistically significant).[2] There was no significant effect of INTERVAL SIZE and no significant interaction, while SPEAKER was significant [For the 'galã' set—INTERVAL SIZE: F(1,12)=2.569, $p > .05$; SPEAKER: F(2,12)=15.305, $p = .0005$; INTERACTION: F(2,12)=3.934, $p = .05$. For the 'manhã' set—INTERVAL SIZE: F(1,10)=0.835, $p > .05$; SPEAKER: F(2,10)=23.044, $p < .0005$; INTERACTION: F(2,10)=0.362, $p > .05$]. Post hoc comparisons of means between groups (Scheffé) showed no significant effect of INTERVAL SIZE within each speaker's data.

The examination of the effect on slope of interval size yields similar results: INTERVAL SIZE did not affect the speed of the focus fall [For the 'galã' set—INTERVAL SIZE: F(1,12)=0.002, $p > .05$; SPEAKER: F(2,12)=0.082, $p > .05$; INTERACTION: F(2,12)=2.488, $p > .05$. For the 'manhã' set—INTERVAL SIZE: F(1,10)=1.609, $p > .05$; SPEAKER: F(2,10)=3.771, $p > .05$; INTERACTION: F(2,10)=0.755, $p > .05$].

The relation between HtoS0 and LtoS0 provides an additional test to hypothesis (3b). If target alignment is indeed affected by the interstress interval, HtoS0 and LtoS0 should not be correlated. The results, however, show a strong correlation between the alignment of H and L, as can be seen in Figure 7 [$r = 0.767$, $r^2 = 0.588$, $p < .0001$]. Again, hypothesis (3b) is not supported by the data.

FIGURE 7

Overall, the results indicate that the location of the low is independent of the position of the following stress, while it is dependent on the location of the peak. In other words, the results show a tight timing relationship between the H and L targets. This finding is certainly consistent with the bitonal hypothesis in (3c). There is, however, a third version of the phrase accent analysis that is also consistent with the data: the possibility that the phrase accent may show a secondary association not to a postnuclear stressed syllable but to the nuclear accented syllable (as in English nuclear falls - Grice *et al.* 2000). In the two alternative treatments the timing dependence of the low on the peak is expected. The phrase accent alternative, nevertheless, must be rejected for independent reasons. Phrase accents are defined as final in a phrase, that is they follow the last pitch accent (Beckman & Pierrehumbert 1986). In European Portuguese, an early focus fall is followed by a post-focal accent in the last stressed syllable of the phrase (as mentioned in section 1.1; see also Frota 2000:chap 5). As the focus fall is not always phrase-final, the low cannot be explained by a phrase accent that has a secondary association with the nuclear syllable across the last accented syllable of the same phrase.

Note that an analysis in which desequencing is allowed for, as proposed in Gussenhoven (2000) for Roermond Dutch, would not provide an adequate account of the European Portuguese data, either. Under such analysis, a right-edge tone may appear to the left of an accentual tone which is final in its phrase, provided that the edge tone cannot be realised after the accentual tone because there is no room for it in the segmental string. In the Portuguese case, however, we can see no reason why the ordering edge tone-final pitch accent would arise, as the same contour is found irrespective of the number of syllables after the last stressed syllable of the phrase or the length of the intervening stretch between the early focus fall and the post-focal accent.

Consequently, only the bitonal analysis, according to which the low is a trailing tone of a H*+L accent, may account for the focus fall.

3.4. The characterisation of bitonality

We have reached the conclusion that both nuclear falls should be treated as bitonal pitch accents. We are thus compelled to examine the three alternative descriptions of bitonality put forward in (4) above. The three alternatives distinguish among a timing dependence between targets in all bitonal accents (4a), in some of them (4b), or in none of them (4c). Crucially, only in possibility (4b) are leading and trailing tones expected to show different properties. These possibilities were tested by examining slope and interval duration in both nuclear falls in Dataset 1.

As can be seen in Table IV, a significant correlation between DHL and f_0HL was found only in the focus fall. This is a first indication of a contrast between the two bitonal accents, suggesting that slope is a relevant property only for H*+L.

TABLE IV

The results, however, also indicate that there is more to the timing of the targets in the focus fall than a tendency to achieve a constant slope. First, the direction of the correlation is different if the focus fall occurs in the last stressed syllable of the phrase, as in ‘jornaLIStas’, or earlier in the phrase, as in ‘angoLAnas’, indicating that time pressure will prompt speakers to produce steeper slopes. More importantly, as Figure 8 shows, HtoS0 and LtoS0 are more strongly correlated in H*+L than in H+L*. Furthermore, the difference between the two correlation coefficients is highly significant [H*+L: r = 0.932; H+L*: r =0.659; Difference: p < .005]. Clearly, then, a tendency towards a constant duration of the interval between targets prevails in the focus fall.

FIGURE 8

That is, H*+L has both a more constant slope and a more constant timing interval between its targets than H+L*. The second result, in particular, suggests that the relation between targets is different in the two accents.

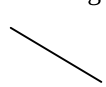
The finding that the two accents contrast does not support alternatives (4a) and (4c), while it is consistent with alternative (4b). Besides the head-initial/head-final difference that characterises H*+L and H+L*, the results show a leading/trailing tone difference in which the leading H tone is timed independently of the T*, whereas the trailing L tone is timed with reference to the T*.

4. Discussion

4.1. Primitives of intonation: targets or configurations?

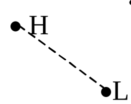
This paper was motivated by issues that spring from the auto-segmental metrical approach to intonational phonology, in particular the need to provide evidence for the appropriate phonological analysis of European Portuguese nuclear falls. Evidence was provided for treating the nuclear falls as bitonal pitch accents, instead of transitions between a single-tone accent and an edge-tone of some sort. In addition, the bitonal accents were shown to display different properties as to the kind of relationship that holds between the two tones of each accent. These findings, however, are also relevant to the targets versus configurations debate around the nature of intonation primes. For the present purposes, the relevant trait of the two positions boils down to the following: if configurations are primitives, then slope and/or duration of the pitch movement should be the consistent properties of pitch accents, and the local f_0 targets would be determined by the properties of the movements; if levels are what tonal events consist of, then the alignment and scaling of local f_0 targets should be the consistent properties of pitch accents, and 'rises' or 'falls' would be determined by the transitions between tonal targets. The first position is the more traditional one, whereas the latter is that assumed by the auto-segmental approach. The two views are schematically represented in (9).

(9) a. configuration: ↘



'fall'

b. tonal targets: HL



'high followed by low'

At first glance, the evidence provided by the contrast between the two bitonal accents looks inconclusive: the properties of H*+L apparently favour (9a), whereas the properties of H+L* favour (9b). A closer observation, however, shows that this contrast offers an argument for the tonal targets view. We have seen that the unstarred tone of the neutral accent is not timed with reference to the starred tone, but with a particular position in the segmental string (i.e. the pre-accented syllable). Therefore, in the neutral fall both tones are aligned with specific segmental positions. Such regular patterns of alignment are what defines H+L*, and not the duration or slope of the fall. Accents like H+L* are thus not expected under the configurations view. As to the focus fall, it looks like a configuration, especially due to the importance of interval duration as a consistent property of H*+L. However, the 'configuration' effect is derived from regular patterns of alignment as well: the peak aligns with the stressed syllable and the low is timed with reference to the peak. Consequently, the interval between the high and the low tends to be constant. In other words, the same mechanisms that underlie the tonal targets view are also capable of accounting for accents like H*+L. Contrasts between unstarred tones timed independently of the starred tone or with reference to it are only possible within a theory that treats tonal targets as primitives.

The EP findings, however, do not support the strong version of the "segmental anchoring" claim proposed by Ladd, Faulkner, Faulkner & Schepman (1999), which takes the tonal target view to its extreme by disallowing accents with the properties of H*+L.

4.2. Leading and trailing tones and pitch accent structure

A complete account of the contrast between the two bitonal accents should deal with the difference in the phonetics of leading and trailing tones described in section 3.4. In the spirit of the intonational phonology approach, such a systematic difference should be taken to reflect a difference in their phonological representation. The standard distinction that characterises bitonal accents is a head-initial/head-final difference, as depicted in (10a) (Pierrehumbert 1980, Beckman & Pierrehumbert 1986). The European Portuguese accents, however, show that leading and trailing tones cannot be simply seen as the unstarred element of a bitonal accent: besides either closely preceding or following the accent's head, the unstarred element may lean on the head or be independent of the head. Along the lines of proposals in Grice (1995*a*,*b*), such a difference can be naturally captured in terms of the structural relations that may hold between tones, as depicted in (10b). This makes the internal organisation of pitch accents similar to that of other phonological entities, such as the prosodic word (as noted by Grice) or the tune (according to proposals in Ladd 1996).

(10) a. standard linear view

b. structured view

If bitonal pitch accents are structured entities, the realisational difference found would follow from a *dominance* contrast: the independence of H, the leading tone, follows from its projection outside the scope of the accent's head, whereas the dependence of L, the trailing tone, follows from its projection inside the head's scope.

The hypothesis of pitch accent structure, which is empirically motivated by findings such as those presented in this paper, opens a new line of research devoted to explore the theoretical and empirical consequences of the proposal. Issues like the independence of precedence and dominance relations or the potential asymmetry between leading and trailing tones are among the topics for future cross-linguistic research in this area of intonational phonology.

5. Conclusion

In this paper, the various competing phonological analyses for the nuclear falls that characterise European Portuguese declarative sentences with a broad or a narrow focus reading have been tested. Evidence was provided for treating both the neutral and the focus nuclear falls as bitonal pitch accents, instead of transitions between phonologically independent tonal events. In addition, the examination of the different alternatives that might account for the relationship between the two tones of a bitonal accent provided evidence for a contrast in the timing of unstarred tones relative to the accent's head. It was shown that the leading tone is timed independently, whereas the trailing tone is timed with reference to the starred tone. Implications of the results for the conception of intonation primes as tonal targets and bitonal accents as structured entities have been discussed.

To the extent that the present investigation has succeed, we have been able to bring phonetic data to bear on the phonological organisation of pitch contours. In future research, we hope to extend this approach to the yet largely unstudied rising contours of European Portuguese.

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Notes

[1] In the materials, there are cases where the ω and ϕ boundaries coincide (e.g. [as angolanas]ϕ). These cases count for both the ω and ϕ boundary cells in Table 2.

[2] Due to the relatively small n per cell, two of the main assumptions underlying the use of ANOVA have been tested and checked for violations, for all sets of data analysed: the normal distribution fit of the dependent variable and the non-correlation between means and standard deviations. No violations that could yield a misleading F statistic were found. The level of significance selected ($p \leq .01$) was also chosen to reduce the probability of error involved in accepting the observed values as representative.

Table I. Syllable alignment of H and L relative to the nuclear syllable (-N/+N respectively indicate the number of syllables before/after the nuclear syllable). Number of cases observed and percentages (in parenthesis). Data from sets 1 and 2.

Nuclear Fall	>-2	-2	-1	Nuclear syllable	+1	+2	>+2	Total
Neutral H	0	0	70(83)	14(17)	0	0	0	84(100)
Contour L	0	0	0	84(100)	0	0	0	84(100)
Focus H	0	0	0	33(65)	18(35)	0	0	51(100)
Contour L	0	0	0	0	32(63)	19(37)	0	51(100)

Table II. Syllable alignment of the L target in the focus contour relative to the ω and ϕ boundaries. _]_ = 1 syllable at either side of the boundary; _σ]σ_ = 2 syllables before/after the boundary. Percentages relative to the possible number of cases (given in parenthesis) for each boundary description. Data from sets 1 and 2.

Boundary	]ω		]ϕ	
Postnuclear σ	_]_	_σ]σ_	_]_	_σ]σ_
+1	63% (51)	100% (9)	46% (35)	100% (25)
+2	35% (26)	29% (34)	21% (42)	56% (18)
Totals	53% (77)	44% (43)	33% (77)	81% (43)

Table III. Syllable alignment of the L target in the focus contour relative to the number of syllables in the interstress interval. Data from sets 1 and 2.

Interval	0	1	2	3
Postnuclear σ	(n=16)	(n=9)	(n=9)	(n=17)
+1	75%	44%	100%	47%
+2	25%	56%	0	53%

Table IV. Summary of the correlation results for DHL/f_0HL. Pearson *r* values. ** = $p \leq .005$; *** = $p \leq .001$. Data from set 1.

DHL/f_0HL	H+L* (angolanas)	H*+L (angolanas)	H+L* (jornalistas)	H*+L (jornalistas)
r	-0.307	0.953***	-0.086	-0.974**

Figure Legends

Figure 1. f_0 contours of the sentence *O pintor retratou uma maNHÃ ÂMbar* ‘The artist painted an amber morning’: panel A, neutral contour; panel B, focus on **maNHÃ**. Both utterances are phrased into one intonational phrase. The relevant stressed syllables are indicated in capitals.

Figure 2. f_0 contours of *CaSAram* ‘They got married’: (A) neutral contour; (B) focus contour. The stressed syllable is in capitals.

Figure 3. f_0 contour of the sentence *O poeta cantou uma* ***maNHÃ*** *angeliCAL* ‘The poet sang an angelic morning’. The sentence is phrased into one intonational phrase. The relevant stressed syllables are indicated in capitals. Narrow/contrastive focus is indicated in bold.

Figure 4. Waveform and f_0 traces for one neutral rendition (A: manhã ÂMbar) and one focus rendition (B: **maNHÃ** âmbar), showing the points at which the H and L targets were measured.

Figure 5. The intervals HtoS0 and LtoV1 for the neutral fall (‘N’eutral and ‘T’opic) and the focus fall (‘F’ocus). Data from set 1 for speakers MV and SF, who show very similar speech rates. Equivalent contrasts are shown by the data from the third speaker.

Figure 6. Whiskers plot for DHL values by interstress interval size. Data from set 2 (‘**gaLÃ** ANda/anDAva’; **maNHÃ** ÂMbar/ang(e)liCAL) for each speaker separately.

Figure 7. The interval LtoS0 as a function of the interval HtoS0 in the focus fall. Data from set 2 (all speakers together).

Figure 8. The interval LtoS0 as a function of the interval HtoS0, for each kind of nuclear fall. Data from set 1 (all speakers together).

Figures 1 to 4 in the hard copy

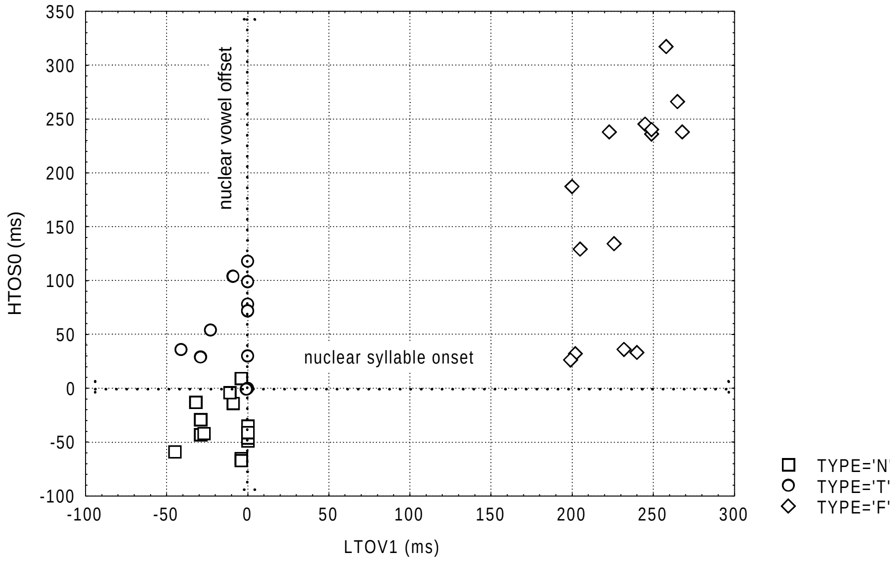
HTOS0 (ms)
LTOV1 (ms)
nuclear vowel offset
nuclear syllable onset
TYPE='N'
TYPE='T'
TYPE='F'

Figure 5

DHL by Interval Size
DHL (ms)
SPEAK: cf
SPEAK: mv
SPEAK: sf
260
220
180
140
100
60
0
1
2
TY: galã
TY: manhã
Interstress Interval size
Mean+SD
Mean-SD
Mean

Figure 6

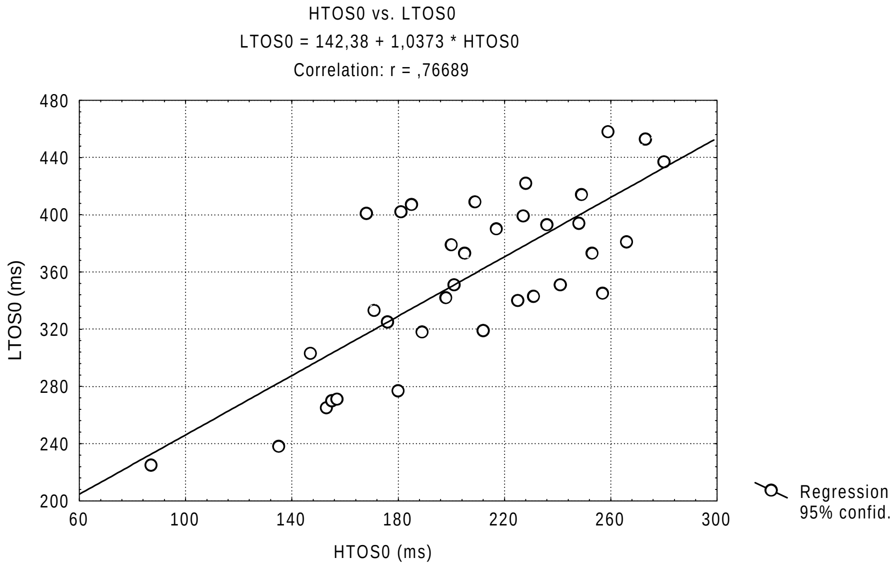
HTOS0 vs. LTOS0
LTOS0 = 142,38 + 1,0373 * HTOS0
Correlation: r = ,76689
LTOS0 (ms)
HTOS0 (ms)
480
440
400
360
320
280
240
200
60
100
140
180
220
260
300
Regression
95% confid.

Figure 7

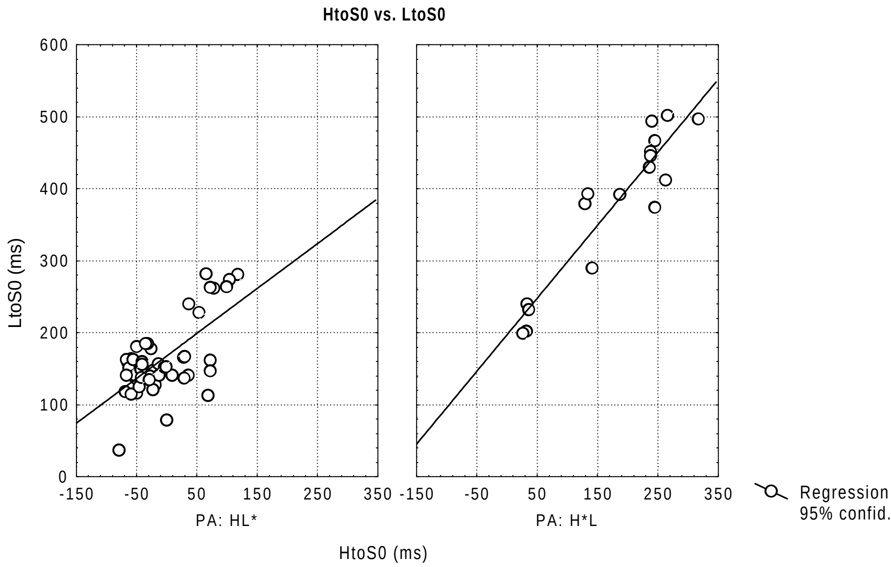
HtoS0 vs. LtoS0
LtoS0 (ms)
600
500
400
300
200
100
0
-150
-50
50
150
250
350
PA: HL*
PA: H*L
HtoS0 (ms)
Regression
95% confid.

Figure 8