Modeling Accentual Phrase Intonation in Slovak and Hungarian

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Abstract: According to Jun and Fletcher (2014), languages with fixed lexical stress towards the edge of the word often include accentual phrases (AP) as a structural prosodic unit between the Prosodic Word (PrWd) and the Intermediate Phrase (ip). APs also tend to show a stable recurrent F0 pattern in various contexts. Slovak and Hungarian both have fixed word-initial lexical stress, and we test the hypothesis that APs are consistently marked with stable F0 contours, which is a precondition for their relevance in the intonational phonologies of the two languages. We employ linear and second-order polynomial stylizations of F0 throughout putative APs and intonation phrases (IPs) in a corpus of spontaneous utterances in Slovak and Hungarian from collaborative dialogues. The results show that these putative APs have consistent F0 contour patterns that are differentiated from the IP pattern in both languages: the Hungarian ones fall, while the Slovak ones rise before they fall.

Keywords: intonational phonology; accentual phrase; Slovak; Hungarian.

1. Introduction

1.1 Prosodic Phrasing

The intonational phonology of a language can be broadly characterized by a systematic relationship between the form and function in three fundamental domains: the division of continuous speech into prosodic units, the distribution of prominences within these units, and the type of F0 movement in the vicinity of the prominences and unit boundaries. This is because the prosodic contrasts in these three domains participate in cuing syntactic, semantic, pragmatic, discourse, and other systematic functional contrasts. Take, for example, the first domain of prosodic phrasing. Virtually any utterance in conversational speech with multiple words might be produced (and perceived) with several optional phrasings. For example, Hirschberg (2002) lists several examples in which the presence vs. absence of a prosodic boundary (or, alternatively, its strength) may disambiguate or affect the syntactic/semantic parsing of an utterance. The scope of the negation in (1) and the attachment of the prepositional phrase in (2) are affected in such a way that in (1) the presence of a boundary facilitates the narrow scope reading of negation ("Bill's unhappiness has led him not to drink.") over the wide scope reading ("Bill does drink but not because of his unhappiness."), and the boundary in (2) facilitates the high attachment of PP *with a telescope* to the verb *saw* ("Sally had a telescope.") over the low attachment to the NP *man* ("The man had a telescope.").

(1) Bill doesn't drink (#) because he's unhappy.

(2) Sally saw a man (#) with a telescope.

Several systematic observations of the relationship between the presence and type of a prosodic boundary on the one hand and the morphological, syntactic, and phonological structure on the other hand lead to the proposal of Prosodic Hierarchy (Selkirk 1986; Nespor and Vogel 1986; Beckman and Pierrehumbert 1986). There have been several additional layers (utterance, foot, mora) and names for the layers introduced (e.g., Prosodic Word ≈ phonological word, intermediate phrase ≈ minor phrase), and thus the hierarchy in (3) represents a schematic simplified version that is relevant for this paper. The fundamental idea, irrespective of the actual names and the number of layers, is extremely fruitful: Prosodic Hierarchy is the source of domains for the application of segmental processes (e.g., flapping in American English), the realization of intonational contours (e.g., pitch range reset), and their interaction (e.g., pre-final lengthening).

(3) Schematic (Simplified) Prosodic Hierarchy

- Intonational Phrase (IP)
- Intermediate Phrase (ip)
- **Accentual Phrase (AP)**
- Prosodic Word (PrWd)
- Syllable (Syl)

The outer levels of the hierarchy (Syllable and Intonational Phrase) are universal and appear in all languages and there is general agreement on their definition. Despite some linkage between the remaining prosodic domains and their correspondence to phonology/

morphology/syntax/semantics, these "inner" domains are less clearly understood. In this paper we focus on Accentual Phrases (APs). They have phrasal stress at the beginning or the end and are often found in languages with fixed word stress and seldom in languages with variable lexical stress (e.g., Farsi). Additionally, the pitch contours in APs show a regular pattern: rising, falling, or rising-falling (Jun and Fletcher 2014). Nevertheless, the definition of an AP is not unproblematic. For example, Jun and Fletcher (2014, 12), describing the difference between an AP and ip, state that durationally, APs "can have minor or no phrase final lengthening. An ip typically includes a few words or APs and is the domain of pitch reset, though not always marked by a boundary tone, and has a medium degree of phrase-final lengthening (i.e., weaker than IP-final lengthening)." The meaning of "weak," "medium," and "minor" in this description requires further clarification.

In addition to this complex, and at times vague, relationship between a phonological construct such as the AP and its phonetic realization, this domain might be susceptible to "low" and seemingly non-structural effects such as the number of constituents within a domain. For example, Jun and Fougeron (2002, 24) observe that in French, "when an AP is longer than six syllables and contains two content words, the string will be produced in two APs with each content word forming one AP." And Frota and Vigário (2007) observe that prosodic length in terms of the number of syllables affects the placement of AP boundaries in Standard European Portuguese.

One of our goals in this paper is to add to the understanding of APs within the Prosodic Hierarchy by investigating the prosodic phrasing of Slovak and Hungarian, two languages whose characteristics facilitate the relevance of APs for their intonational phonologies.

1.2 Slovak and Hungarian

Slovak and Hungarian are genetically unrelated languages that, however, are geographical neighbors and have a long history of contact and mutual influence. Slovak is a West Slavic language with about five million speakers in Slovakia and Hungarian is a Finno-Ugric language with about 10 million speakers in Hungary and significant minorities in Slovakia, Romania, and other neighboring countries. They share several prosodic characteristics, most importantly the fixed position of lexical word stress on the left-most syllable of a Prosodic Word and very weak and often variable tendencies for secondary stress. Additionally, the left-most primary stress is marked with relatively weak phonetic cues such as minimal vowel quality difference between stressed and unstressed syllables (Beňuš and Mády 2010), weak durational cuing of the stressed syllables, partly as a result of the phonemic contrast in vowel duration in both languages, and the absence of clear robust marking of word stress with intensity and F0.

Regarding prosodic phrasing, initial efforts at building a ToBI system for Slovak prosody do not propose units below intermediate phrases (Rusko et al. 2007). On the other hand, previous work on Hungarian suggests that content words are produced with pitch accents that delimit the left edge of a smaller prosodic domain within larger intonational phrases. Hunyadi (2002) refers to this domain as a phonological phrase and Varga (2002) defines this domain intonationally with a set of "character contours." Given the description of APs in other languages by Jun and Fletcher (2014) discussed in Section 1.1 above (edge-most phrasal stress and regular characteristic F0 contours), this prosodic domain of Hungarian might correspond to APs.

1.3 Approach: From Accent Groups (AGs) to Accentual Phrases (APs)

The overall goal of our research is to determine if the intonational phonology of Slovak and Hungarian utilizes the prosodic domain between the Prosodic Word and Intermediate Phrase. There are two steps to reaching this goal. First, we have to establish if speakers consistently produce this prosodic domain with systematic prosodic marking. Second, we have to test if the presence of this prosodic domain is systematically linked to some linguistic contrasts in both production and perception of speech. The current paper tests the first step, and, to preview, provides a positive answer for both languages. The second step is the topic of our future research.

To answer the question in the first step, we take a bottom-up approach. Given that the guidelines for identifying intermediate and accentual phrases top-down are tentative and often rely on intuition, we define an accent group (AG) as a rhythmic unit that stretches from an accented syllable until the last unaccented syllable before the next accent or the end of the IP. There are several studies suggesting high inter-annotator agreement and reliability in the task of identifying pitch-accented syllables (see Wightman [2002] for a review). Once the accents are marked, we then test if the AGs are consistently characterized by a given type of F0 contours. If the answer is positive, the AGs would fulfill both criteria for Accent Phrases (APs) listed in Jun and Fletcher (2014): edge-prominence (left-most in both Slovak and Hungarian) and a consistent shape of the F0 contour. We first review the results based on comparing AG contour deviance from overall IP contours through linear stylization of F0 presented in Mády et al. (2014) and then extend the results by employing F0 stylization with second-order polynomials.

2. Methodology

2.1 Corpus

We performed a random selection of spontaneous utterances in Slovak and Hungarian that formed a single Intonational Phrase (IP) from corpora of Slovak and Hungarian collaborative dialogues. There were three requirements for these IPs. First, they had to have at least two pitch accents to guarantee that the Accent Groups (AGs), defined bottom-up as a rhythmic unit spanning the accented syllable and all the following unaccented syllables, do not correspond to IPs. Second, to assure the consistency of the data and to make the F0 stylization robust, only IPs with a low phrase-final boundary tone were allowed. Finally, to achieve a representative sample and good coverage of the variations between speakers, we selected five utterances each from 10 Slovak and 10 Hungarian speakers, respectively. Both IPs and pitch accents were identified manually by a phonetically trained native speaker (Štefan Beňuš and Katalin Mády) on the basis of audible and visible pitch movements in the signal and perceived prominence on the word. This procedure gave us 50 Slovak IPs containing 157 AGs and 50 Hungarian IPs containing 130 accent groups as the corpus for this study.

2.2 F0 Stylization and Measures

2.2.1 Pre-processing

F0 was extracted by autocorrelation (Praat 5.3, sample rate 100 Hz). Voiceless parts of the utterances and F0 outliers were interpolated by piecewise cubic splines (de Boor 1978). The contour was then smoothed by Savitzky-Golay filtering (Savitzky and Golay 1964) using third-order polynomials in five sample windows and transformed to semitones relative to a base value. This base value was set to the F0 median below the fifth percentile of an utterance and served to normalize F0 with respect to its overall level. Figure 1 illustrates the result of this pre-processing.

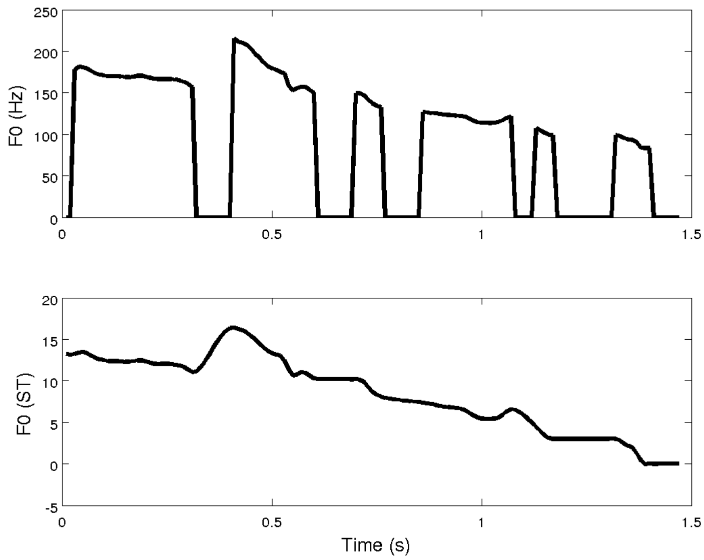

Figure 1. Pre-processing example.

2.2.2 Linear Stylization: Quantifying Deviation between Accent Groups and Intonational Phrases

We assume that the F0 correlates for the presence of accentual phrases are: (1) local-level deviations between AGs and the IP and (2) prominent F0 movements within AGs expressed in high F0 ranges. In order to quantify these two aspects we first carried out a linear level and range stylization within the IPs and AGs and then calculated the distance between the AG and IP stylization parameters.

To capture the F0 register in terms of its level and range (Rietveld and Vermillion 2003) we fitted a base-, a mid-, and a topline separately for the IP and all the AGs within this IP. The midline represents the F0 level, whereas the base- and topline provide the F0 range information. The robust fitting procedure, which is explained in more detail in Reichel and Mády (2013), consists of the following steps:

- A window with a length of 200 ms is shifted along the F0 vector with a step size of 10 ms;
- within each window three F0 medians are calculated: one for the baseline based on the values below the 10th percentile, one for the topline based on the values above the 90th percentile, and one for the midline based on all the values;
- within each of the three resulting median sequences outliers are replaced by linear interpolation and a linear polynomial is fitted.

It is shown in Reichel and Mády (2014) that this approach is more robust for base- and topline fitting than the classical fitting approach of Liebermann et al. (1985) since it does not need to rely on the detection of noisy peaks and valleys. An example result of this linearization approach is shown in Figure 2.

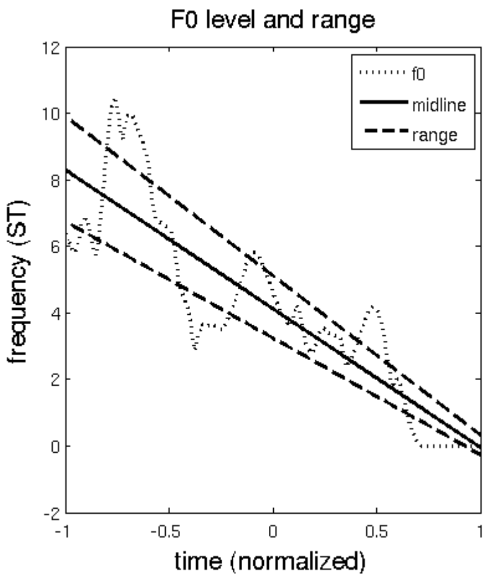

Figure 2. Linear level and range stylization. The level course is represented by the midline, the range course by the time-varying distance between the base- and topline.

From these mathematical representations of F0 contours, the following measures were derived:

- the slope of the AG midline (*mlSlope*);
- the absolute slope difference of the AG and IP midlines (*mlSlopeDiff*);
- the mean squared deviation of the AG line from the corresponding section of the IP line (*mlRms*);
- the absolute value of the difference between the initial F0 value of the AG midline and the corresponding IP midline value (*mlInitDiff*);
- the absolute value of the difference between the final F0 value of the AG midline and the corresponding IP midline value (*mlFinDiff*);
- the AG range is represented by the root mean squared deviation between the AG top- and baseline (*rangeRms*).

The expected acoustic correlates for the presence of accentual phrases are prominent F0 movements reflected in high AG range values (*rangeRms*), as well as considerable local-level deviations between the AG and the IP expressed in high values for the features *mlSlopeDiff*, *mlRms*, *mlInitYDiff*, and *mlFinYDiff*. To test the null hypothesis (that AGs do not differ significantly from IPs with respect to the F0 parameters that were investigated), we used a one-sample t-test for the features and compared it to a sample with mean = 0. A significant difference would point to a difference in the AG and IP marking for a language. To test the hypothesis that Slovak and Hungarian differ in their marking of AGs, we compared the Hungarian and Slovak samples to each other. If the data were not normally distributed, the Mann-Whitney test was carried out instead. The equality of variances was tested by the Levene test, which is also applicable to non-normally distributed data. The significance level was set to $p = 0.05$.

2.2.3 Quadratic Stylization: F0 Shape in Accent Groups

Within each AG a second-order polynomial was fitted to the F0 contour. In order to compare the parameters across different AG lengths, the time was normalized to the interval −1 to 1. The curvature of the F0 contour was quantified in terms of the quadratic coefficient. Negative values represent concave (rising-falling), as in the left-hand panel of Figure 3, positive values convex (falling-rising) shapes, as in the middle panel of Figure 3, and a value near zero indicates a low curvature and thus a contour with an almost linear shape, as in the right-hand panel of Figure 3.

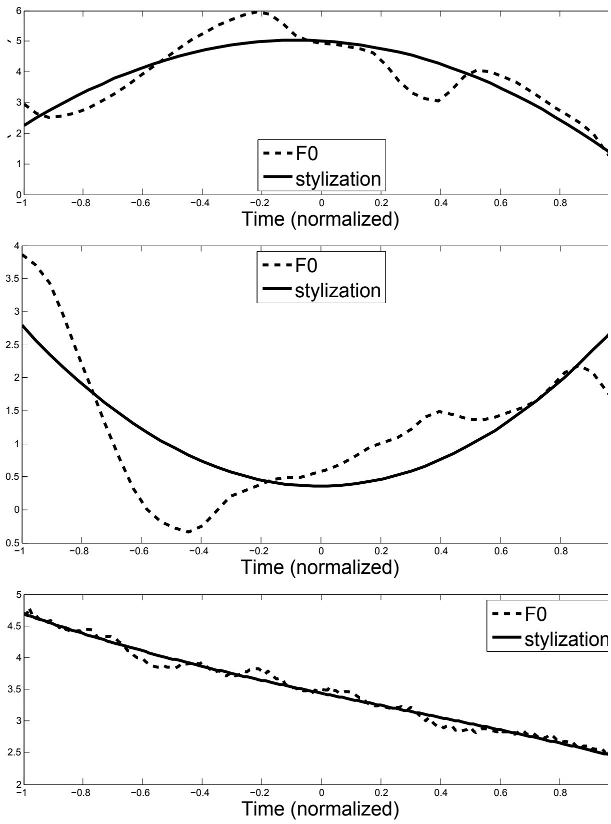

Figure 3. Examples of quadratic stylization: typical Slovak rising-falling contour (top); typical Hungarian falling-rising or falling contours (middle, bottom).

Linear and parabolic shapes were furthermore distinguished by locating the peak or valley of the fitted parabola. By definition, for linear shapes the turning point is located outside the AG time interval, whereas for parabolic shapes it is inside this interval.

3. Results

3.1 Linear Measures

This section summarizes the patterns observed in the analysis of linear stylization. Compared to Mády et al. (2014), in which detailed information, figures, and statistical results on these data are described, here we used a more conservative method for eliminating outliers. All the major patterns remained but we report less robust findings concerning the local differences between the AG and the IP at the beginning and at the end of the AG.

The midline slopes (*mlSlope*) were more often negative (= falling) in Hungarian than in Slovak, and the fall was steeper than in Slovak. The measures *mlSlopeDiff* and *mlRms* indicate to what extent the AG midlines deviate from the IP midlines. While the first parameter defines the angle of the two midlines, the second gives the distance between the two. If two midlines are parallel but distant, *mlSlopeDiff* is zero, while *mlRms* is large. The analysis revealed that the AG midline slopes differ considerably from the IP midlines in both languages (i.e., the differences differed significantly from zero). The slope differences were significantly larger in Hungarian than in Slovak.

The measures *mlInitYDiff* and *mlFinYDiff* are measures of the local differences in the AG vs. the IP at the beginning and at the end of the AG. Since the measure contains the absolute difference between the onset/offset of the AG and the IP, a larger value refers to a greater deviation. There was only one significant result: *mlInitYDiff* differed significantly from zero in Hungarian. In other words, AGs begin with a different F0 in Hungarian than would be predicted on the basis of the IP. Note, however, that these measures express the absolute difference and do not provide information about the direction of this difference.

Finally, the ranges between the base- and the topline were compared. It was assumed that if an AG is an independent prosodic unit in its own right, then it will have a larger range in the domain of the AG than would be expected on the basis of the corresponding part of the IP. This expectation was confirmed for both languages with values considerably higher than zero. However, no difference between Hungarian and Slovak was found.

The above results showed that Hungarian AG slopes tend to be falling, and that they differ from the overall midline slope of the entire IP. These tendencies were also present in Slovak, but to a smaller extent.

3.2 Quadratic Measures

The AG contours were analyzed on the basis of the coefficient c_2, representing the curvature of the polynomial functions that best fitted these contours. It should be recalled from Section 2.2.3 that negative coefficients indicate a rising-falling F0 pattern (the higher the absolute value of c_2, the more pronounced the rise-fall), positive coefficients indicate a falling-rising contour, and values around zero show a low curvature, i.e., a close approximation of a linear shape. The values for the quadratic coefficient c_2 are shown in the left-hand panel of Figure 4 and the difference between the languages is highly significant. The majority of the Hungarian contours had a flat or falling-rising pattern, whereas the F0 contours in the Slovak AGs were typically rising-falling and steeper than in Hungarian.

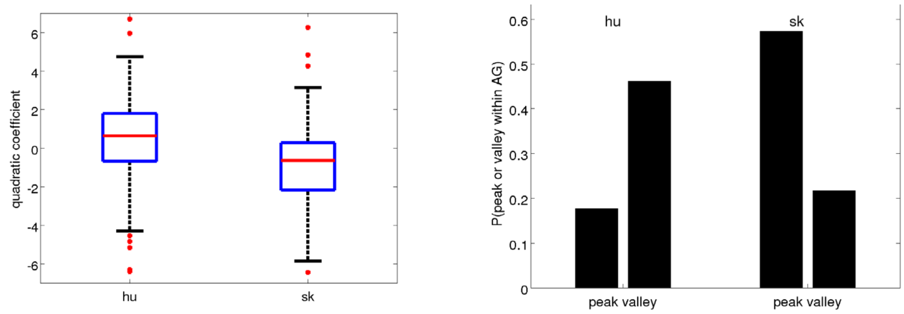

Figure 4. Values of c_2 in Hungarian (*hu*) and Slovak (*sk*) for polynomials fitting F0 contours within AGs (left), and probabilities that the peak or valley of a parabola is located within the corresponding AG (right).

Given that the F0 midlines in the Hungarian AGs were previously shown to be falling, it is interesting that about one third of the quadratic coefficients was negative in Hungarian. One possibility is that a falling F0 contour is stylized as the falling part of a parabola, and the peak is located to the left of the midpoint of the AG, or even preceding the onset of the AG.

The location of the peaks of all the concave parabolas, i.e., those with negative c_2, and the valleys of the convex ones, i.e., those with negative c_2, was algorithmically identified in the data. On the basis of a chi-square test, we found that the relative frequency *P* with which a polynomial peak or valley fell within the range of the AG was significantly higher for Slovak than for Hungarian ($P = 0.79$ for Slovak, $P = 0.64$ for Hungarian, $X^2 = 8.1204$, $p = 0.0044$), which indicates that the Slovak AG contours were less linear and showed a more pronounced curvature. Besides, significantly more Slovak AGs contained a polynomial F0 peak ($P = 0.57$ for Slovak, $P = 0.18$ for Hungarian, $X^2 = = 46.7952$, $p < 0.0001$). The right-hand panel of Figure 4 shows these relative probabilities. While in Hungarian, valleys rather than peaks are likely to occur in AG-medial position, the situation is reversed for Slovak: peaks but not valleys are likely to occur within the AG. Hence, the analysis of the quadratic measures shows that the dominant contour in the Slovak AGs is a rise-fall, while it is a fall (or fall-rise) in the Hungarian AGs.

4. Discussion and Conclusions

The goal of the paper was to determine if Slovak and Hungarian speakers consistently mark a prosodic domain between the syllable and the intermediate phrase with stable F0 contours. Our approach relied on the robust bottom-up creation of a rhythmic unit we called the Accent Group (AG), spanning the initial accented syllable up to the next accent or end of an intonational phrase (IP). AGs are by definition edge-marked since lexical stress in both Slovak and Hungarian is on the initial syllable of a Prosodic Word. The question we set out to answer was if AGs are produced with a consistent F0 contour pattern that is different from the overall contour for the entire IP. The measurements based on the linear stylization of AG and IP contours suggested that AG contours are typically falling in Hungarian and clearly different from IP contours, whereas in Slovak this tendency was much weaker.

The innovative extension of this finding in this paper is the pattern in the quadratic stylization of AG contours. The values for the quadratic coefficient c_2 show that Slovak AG contours are predominantly rising-falling, which explains the weak effect observed for the linear-based measures in the Slovak data. Moreover, the maxima of these Slovak concave contours (F0 peaks) are frequently contained within the time interval of the AG. On the other hand, the quadratic fitting of the Hungarian AG contours points to a much less homogeneous pattern compared to Slovak. To summarize, AGs have consistent F0 contour patterns that are differentiated from the IP pattern in both languages: the Hungarian ones fall, while the Slovak ones rise before they fall. Therefore, both Slovak and Hungarian AGs are good candidates for the Accent Phrase (AP) as a prosodic domain of the intonational phonology of the respective languages.

In the absence of the data for the second step of our approach to determining the relevance of APs for the intonational phonologies of Slovak and Hungarian (systematic linguistic contrast marked by AP boundaries; Section 1.3), we point out that one of the functions of the putative AP boundaries is to enhance the perception of emphasis on the following word. As discussed in Section 1.2, both languages have relatively weak phonetic marking of accents on lexically stressed syllables. It is plausible that there is a cross-linguistic trade-off in marking prominence: some languages, such as English, use large pitch changes in the vicinity of accented syllables accompanied by increases in duration and intensity, whereas other languages use weaker cues on the accented syllables themselves but insert a prosodic boundary to enhance the perception of prominence on the material following this boundary.

This idea might explain our informal observation that speakers not familiar with Slovak or Hungarian commonly have difficulty perceiving the word-initial prominence and that native speakers tend to insert salient breaks, even pauses, at syntactically weak junctures, such as between a determiner and a noun, which, however, would be legitimate AP boundaries (Mády and Kleber 2010). In this sense, our observations are similar to the suggestion of Wagner and Malisz (2012) after examining the effects of intensity, pitch movement, and duration on Polish word stress and sentence prominence that fixed penultimate word stress is a highly influential "expectation" perceived by native speakers but not consistently signaled in the acoustic signal. We suggest that this consistency might be found globally in larger prosodic domains rather than locally on the accented syllables.

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