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Local and Global Acoustic Correlates of Information Structure in Bulgarian

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Abstract

In this study the local and global prosodic exponents of information structure are examined in the production of six Bulgarian question-answer elicited sentences under different focus conditions (broad focus and non-contrastive and contrastive narrow focus). Local cues are the phonetic properties of the nuclear accented syllables, while global cues reflect broader phonetic patterns in the intervals before and after the nuclear accented syllable, which in some cases vary independently of the tonal accent. Results show that speakers consistently discriminate broad and narrow focus by both local and global acoustic cues. Contrastive and non-contrastive accents are differentiated exclusively by local cues, but only when the focus is early in the sentence.

Index Terms: information structure, prosody, local and global cues, Bulgarian

1. Introduction

Most languages employ prominence-giving mechanisms to mark the relative informational importance of particular words in a phrase, often combined with word order and special lexical items or syntactic constructions. It is common to distinguish three elements of information structure (IS, e.g. [19]): ‘topic’ (the subject matter, on which new information is to be offered), ‘focus’ (the new information offered) and the ‘given information’ (information given previously or assumed to be known). These elements can be realized prosodically by means of a ‘topic accent’, a ‘focus accent’ or by ‘de-accentuation’. At some basic production level, the speaker invests more effort in accented words compared to the words conveying given information, with the consequent acoustic effects of greater duration and intensity, higher or changing fundamental frequency (F0) and in some way more distinct spectral properties [10, 17, 24, 33]. However, there is evidence that languages differ in the amount each of the acoustic dimensions changes under accentuation [4, 25, 26] and there is considerable debate about which properties are used by the listener to identify prominent words or syllables. Pitch (measured as F0) is often seen as dominant [28, 14, 18], but duration [9, 20], intensity [9, 24, 35] and even voice quality [33] have also been singled out as important if not dominant determinants of perceived prominence.

Depending on the information provided by the pre-context, the focused part of a phrase can be restricted to one word – ‘narrow focus’ – or extend over much of the phrase – ‘broad focus’. Within ‘narrow focus’, there is considerable disagreement in the literature about whether ‘contrastive’ and ‘non-contrastive’ focus are two distinct IS categories. Clearly, the context may or may not specify a semantic entity to which the focused word is in explicit contrast, providing a textual basis for a distinction. However, e.g. Rooth [31] sees an implicit contrast in any narrow focus; any expression has two semantic representations: the meaning of the expression itself and a set

of alternatives. In the case of explicit contrast the alternative is known, but for Rooth the meaning of the expression does not change if the alternatives are not explicit.

Clear prosodic evidence for or against a contrastive – non-contrastive distinction is not apparent from the literature. Some have argued that there is no difference [16, 12, 34], while others have found evidence and argued that some acoustic features differ between contrastively vs. non-contrastively focused elements [13, 27, 7, 23].

Somewhat surprisingly perhaps, there is also disagreement about the reliability of the broad – narrow focus distinction. Of course, acceptance of the same utterance following both a pre-context cueing narrow focus and one cueing broad focus can only occur when the narrow focus is on the final lexical item. But given this condition, equal acceptance has been shown in several studies [11, 21, 37], while others claim that their subjects have consistently been able to make a distinction [8, 32].

In this paper, the prosodic exponents of broad focus and of non-contrastive and contrastive narrow focus are examined in the Sofia variety of Contemporary Standard Bulgarian.

Important factors in the realization of the information structure in Bulgarian utterances are:

- *word order*, remarkably flexible and discourse conditioned, as in all Slavic languages;
- morphological category of *definiteness*, unusual in the Slavic language family;
- *clitic replication* of nominal material;
- intonation.

Avgustinova [5] models the IS of Bulgarian utterances as interplay of the first three factors, while Miševa [29] and Nikov & Miševa [22] address the role of intonation. They experimentally investigated the regularities of F0 changes expressing phonetic prominence presented in terms of the traditional theme-rheme partitioning of the sentence. They conclude that the linguistically relevant phonetic characteristic of the given material (theme) is simply the absence of accentual prominence, i.e. de-accentuation. New material (rheme) shows the same intonational pattern in narrow and broad focus, but the accentual contrast between the prominent and the surrounding syllables is greater in narrow than in broad focus.

Andreeva et al. [1], Andreeva [2] and Avgustinova & Andreeva [6] adopted the terminology used in the Information Packaging approach in [36], where the basic focus-ground (cf. rheme and theme) articulation of the utterance is further refined by dividing the ground into link (what the focus is about) and tail (how the focus fits in the context). Contrary to the findings in [22, 29] they report that the underlying (phonological) pitch accent pattern for the thematic material is L*+H. Differences in the particular phonetic realizations depend on how the theme is realized on the surface, i.e. as a link (non-final in the intonational phrase) or a tail (final). In the link (pre-nuclear) the underlying pattern is realized phonetically as a gliding (slow) F0 rise from a low target within the accented syllable up to the next syllable (if there is enough syllabic ma-

terial), otherwise only within the syllable itself. In the tail (post-nuclear) the underlying pattern is not realized phonetically, i.e. there is a phonological rule deleting all pitch accents after the nuclear tone. In the opposition narrow vs. broad focus the underlying H* for the nucleus is realized with an emphasis [+raised peak] in the marked member of the opposition (i.e. narrow focus). In the case of a contrastive narrow focus, the phonetic realization of the shape of the underlying H* is also different, namely H* > [+raised peak; +delayed peak].

In this article, the question we would like to address is whether Standard Bulgarian distinguishes between different types of focus: a) non-contrastive and contrastive narrow focus, and b) broad and narrow focus. We first investigate the local acoustic cues in the nuclear syllable in terms of duration, F0 and intensity. Bruce [13] claimed that the focus domain is larger than the focused constituent and can affect the prosodic-acoustic realization of the whole sentence. Therefore, we shall also investigate the global effects of the IS on duration, F0 and intensity in the part of the utterance preceding and following the nuclear accent.

2. Material and Methods

The Bulgarian data that were used in this study were taken from an existing speech corpus consisting of read speech for several languages [4]. The stimulus material consisted of sentences with a fixed, canonical word order *subject < verb < direct object < indirect object < oblique*. This increases the role of prosody as an information-structuring factor, allowing us to focus on the acoustic correlates of different focus types. There were two critical words (CWs) in the sentence which could be realized with prominence, one early (CW1) and one late in the sentence (CW2). For each sentence, a number of questions were devised to elicit a) a *broad-focus* response, b) a response with a *non-contrastive narrow focus* on the early and c) on the late CW and d) a *contrastive focus* on the early and e) on the late CW. The sentences (with the critical words underlined) are:

1. Димо Данев гледа две деца.
Dimo Danev gleda dve detsa.
Dimo Danev looks after two children.
2. Бате Стефан взе седем книги.
Bate Stefan vze sedem knigi.
The elder Brother Stefan has taken seven books.
3. Играх на дама без кака ти.
Igrax na dama bez kaka ti.
I played draughts without your older sister.
4. Бате Мани пи тъмна бира.
Bate Mani pi tamna bira.
The elder Brother was drinking dark beer.
5. Дим Данев пях три пъти.
Dim Danev pja tri pati.
Dim Danev has sung three times.
6. Каква Нина търси черен хляб.
Kaka Nina tarši čeren xlyab.
The elder sister Nina is looking for dark bread.

The Bulgarian data corpus consists of 1080 sentences in total (6 speakers x 6 sentences x 5 focus conditions x 6 repetitions). In this article we present analysis results for local measurements in the CW for all sentence repetitions. We also present a more detailed analysis of the global prosodic patterns in the entire sentence for the first three of the six available repetitions.

2.1. Recordings and processing

Six regionally homogeneous speakers of Contemporary Standard Bulgarian as spoken in Sofia (3 female, 3 male) were recorded in a sound-treated studio. They read aloud each of the above sentences from a PowerPoint presentation in response to pre-recorded questions. The sentences and the questions eliciting different focus responses were pseudo-randomized and offered to the informants in six blocks, resulting in six repetitions of each sentence for each focus condition. The subjects were paid for participation.

The recordings were made using an AKG C420MHP headset on a Tascam DA-P1 DAT recorder and transferred digitally via the optical channel to a PC using the Kay Elemetrics MultiSpeech speech signal processing program.

Segmentation, labelling with SAMPA and further processing were done using the Kiel XASSP speech signal analysis package. Six labelling assistants were allocated different sentences (to maximize labelling consistency across conditions within each sentence) and segmentation problems were regularly discussed and decided with the authors at group level. In addition to the segmental labelling the pitch accents were also labelled by the first author, using BG-ToBI [2], with the peak alignment of the L(ow) and H(igh) targets explicitly specified. The positions of the F0 maxima and minima were double-checked by an automatic procedure for which the Praat pitch tracker was used.

2.2. Acoustic measurements

Local and global acoustic measures were calculated using Praat scripts and operationalized as described in the two following subsections.

2.2.1. Local measurements

Local measurements of duration, F0 and intensity were made in the CWs in all the sentences read aloud by the informants.

a) Duration

Durations were measured for the stressed syllables of the CWs. The durations of the vowels in these syllables were also measured. Since all analyses and comparisons were carried out on individual sentences spoken in different focus conditions, it was possible to normalize all durational measurements as a percentage of the mean duration of the corresponding unit in the sentence.

b) Fundamental frequency

F0 was calculated as the mean fundamental frequency [Hz] across the syllable nucleus (vowel or syllabic sonorant) of the lexically stressed syllable of the CW. These values were also normalized by expressing them as percentages of the mean overall F0 of the sentence.

As a measure of peak alignment, the above absolute temporal distance from the F0 peak to syllable onset and rhyme onset were calculated. In order to compensate for the varying segmental durations on peak alignment, the above absolute measures were converted to relative measures, taken as a proportion of syllable and rhyme durations.

c) Energy

Energy was measured in two ways. First, as the mean intensity [dB] of the stressed vowel in the CW. These intensity values were normalized by subtracting the sentence intensity. Second, energy was measured as the spectral balance in the vowel.

This was computed as the difference in energy between the 70-1000 Hz and 1200-5000 Hz frequency bands.

2.2.2. Global measurements

Global measurements of duration, F0 and energy were made for the first three sentence repetitions by each speaker in each condition (focus type x sentence).

a) Duration

Durations were measured for the beginning of the sentence (sb) up to the focused syllable and for the sentence end (se) starting from the end of focused syllable. The values were normalized for speaking rate by calculating the percentage of the total sentence duration.

Since the number of syllables in the sentences varies, the tempo of sb and se were computed by dividing their duration by the number of syllables in the interval.

b) Fundamental frequency

In addition to mean F0 and peak alignment (section 2.2.1), the minimum F0 value preceding (L) and following the peak (Lpost) was measured, and the pitch excursion between the preceding F0 minimum and the peak (LH) and between the peak and the following F0 minimum (HLpost) was computed (s. Figure 1).

Individual F0 differences were removed by converting the obtained measurements to semitones by means of the following formula:

$$39.863 * \log_{10}(\text{Maximum/Minimum})$$

Mean F0 values for sb and se were also computed and normalized by converting them to percentages of the sentence mean.

c) Energy

The intensity of sb and se were also measured and normalized using the same procedure as for the stressed vowels.

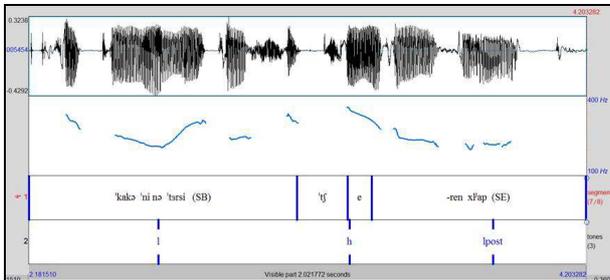


Figure 1: Labeling example (sentence 6, narrow non-contrastive focus on CW2).

2.3. Statistical analysis

The effect of focus condition was analyzed as a within-subjects factor separately for the local and global measurements in a mixed between-within MANOVA, with subject as a between-subjects factor. We report univariate tests with Greenhouse-Geisser estimates of F. These were verified with the multivariate Pillai's trace statistic; cells were equal in size. Separate Bonferroni post-hoc tests were carried out, if appropriate. The confidence level was set at $\alpha=0.05$.

3. Results

In our data, the narrow focus is realized as (L+)H* pitch accents (except by speaker SP6). When the focus is realized on CW1 the H target is mostly reached close to the end of the accented syllable (93 %); when the focus is realized on CW2 die

H target is reached close to the beginning of the accented syllable (85%). In broad focus condition, we observe H+!H*/L* with early peak alignment. Speakers vary as to their preferred choice of phonologically specified accent types and their phonetic realization. SP6 exclusively uses downstepped nuclear accents (H+!H*) in the narrow focus condition regardless of the position within the sentence, SP5 has a strong preference for downstepped nuclear accents (H+!H*) in the narrow focus condition on CW2 and speakers 1, 2, 4 and 5 show a preference for late peak alignment in the contrastive focus on CW1. The number of the pitch accents with early and late peak alignment used in the different focus conditions is summarized in Table 1.

Table 1: Distribution early versus late peak alignments (left-hand column) per focus condition and speaker (note: only 2 sentences were analyzed for broad focus).

		speaker						total
		SP1	SP2	SP3	SP4	SP5	SP6	
E	CW2 broad	6	6	6	6	6	6	36
A	CW2 nc	18	18	17	17	18	18	106
R	CW2 c	16	17	18	13	18	18	100
L	CW1 nc	7	5	10	2	0	16	40
Y	CW1 c	2	4	12	4	1	16	39
total		49	50	63	42	43	74	321
L A T E	CW2 broad	0	0	0	0	0	0	0
	CW2 nc	0	0	1	1	0	0	2
	CW2 c	2	1	0	5	0	0	8
	CW1 nc	11	13	8	16	18	2	68
	CW1 c	16	14	6	14	17	2	69
total		29	28	15	36	35	4	147

In Bulgarian broad focus sentences, each content word is accented. In our data, CW2 is the last content word in sentences 3 and 5, while it is followed by another content word in the remaining sentences. To determine whether the acoustic realization of sentences in which only the object (CW2) carries a narrow focus differs systematically from those in which the entire event is focused (broad focus), we analyze sentences 3 and 5 separately from the other sentences. To investigate whether speakers prosodically differentiate non-contrastive and contrastive narrow focus we analyze all sentences, excluding the broad focus conditions. Sentences containing an early focus (on CW1) are analyzed separately from those containing a late focus (on CW2).

3.1. Local acoustic correlates of IS

The results from the statistical analysis of the local acoustic measurements (see section 2.2.1) for all focus conditions are summarized in Table 2.

3.1.1. Broad vs. Narrow

When the nuclear accent falls on CW2, both focus condition ($F[2, 90] = 29.739, p<0.001$) and speaker ($F[5, 90] = 35.307, p<0.001$) have a significant effect on the peak alignment. Moreover, there is a significant interaction between the two factors ($F[10, 90] = 5.012, p<0.001$). Speakers 1–4 align the F0 peak substantially earlier in the broad focus condition than in narrow focus, while speakers 5 and 6 do not differentiate between the two focus conditions.

Broad focus differs from narrow focus in that it has shorter syllable durations ($F[1,724; 51.717] = 211.658, p<0.001$), lower vowel intensity ($F[1.458; 41.117] = 539.372, p<0.001$), greater spectral tilt in the vowel ($F[2.467; 69.081] = 32.807,$

$p < 0.001$) and a lower F0 in the vowel (F [1.720; 43.005] = 340.662, $p < 0.001$). This F0 difference reflects the use of a different nuclear accent types: H+!H*/L* for broad and (L+)H* for narrow focus.

Table 2: *Main effects for focus condition and subject on local acoustic measurements and interactions (***) $p < 0.001$*

parameter	focus cond.	subject	interaction
nuclear accent on CW2 (broad vs. late)			
peak alignment	***	***	***
syll. duration	***	n.s.	n.s.
vowel intensity	***	***	***
vowel SpecTilt	***	***	***
vowel F0 mean	***	***	***
nuclear accent on CW1 (contr. vs. non-contr.)			
vowel duration	***	n.s.	n.s.
syll. duration	***	n.s.	n.s.

3.1.2. Contrast vs. Non-Contrast

Contrastive and non-contrastive focus is realized identically on CW2. When the focus is realized on CW1, the pitch accents are identical, but speakers produce a systematically longer vowel (F [2.218; 66.526] = 42.542, $p < 0.001$) and syllable durations (F [2.281; 60.636] = 267.788, $p < 0.001$) in the contrastive focus condition.

3.2. Global acoustic correlates of IS

Table 3 summarizes the results from the statistical analysis of the global acoustic measurements for all focus conditions (see section 2.2.2).

Table 3: *Main effects for focus condition and subject on global acoustic measurements and interactions (***) $p < 0.001$*

parameter	focus	subject	interaction
pre-nuclear accent on CW1 (broad vs. late)			
vowel intensity	***	n.s.	n.s.
nuclear accent on CW2 (broad vs. late)			
excursion LH	***	***	***
excursion HLpost	***	***	***
tempo pre-nuclear (sb)	***	***	n.s.
intensity pre-nuclear (sb)	***	***	***
intensity post-nuclear (se)	***	***	n.s.

3.2.1. Broad vs. Narrow

Considering non-local (global) effects, we also investigated the realization of CW1 for broad- vs. narrow-focus differences when the nucleus is on CW2. Although the CW1 was not de-accented in narrow focus (compare also [1, 2, 6]), and pitch accents realized in broad and narrow focus conditions were identical (L*+H), we observe a difference in *intensity* in the pre-nuclearly accented CW1 vowel, with a higher vowel intensity in broad than in narrow focus (F [1.717; 51.507] = 631.053, $p < 0.001$), i.e. a measureable weakening of the pre-context in narrow focus on CW2.)

With respect to the pitch excursion (see section 2.2.2), a main effect was found for focus condition for the L-H excursion (F[2, 89] = 33.948, $p < 0.001$) as well as for the H-Lpost excursion (F[2, 89] = 12.607, $p < 0.001$), with larger excursions for narrow focus. There was also a main effect for speaker, both for the L-H excursion (F[5, 89] = 106.959, $p < 0.001$) and for the H-Lpost excursion (F[5, 89] = 122.041, $p < 0.001$). Focus and speaker also interacted significantly (F[10, 89] =

4,932, $p < 0.001$), with only speakers 1-4 differentiating between the broad and narrow focus.

In the broad focus condition, the tempo in the pre-nuclear interval (sb) is lower (F[2, 90] = 6.662, $p < 0.01$) and the intensity is higher than in narrow focus (F[2, 90] = 1.562, $p < 0.01$), while intensity for the post-nuclear interval (se) is lower than in narrow focus (F[2, 90] = 12.582, $p < 0.001$).

Speakers also differed significantly (tempo sb: F[5, 90] = 14.868, $p < 0.001$; intensity sb: F[5, 90] = 55.567, $p < 0.01$; intensity se: F[5, 90] = 11.909, $p < 0.001$). An interaction between speaker and focus condition is only found for intensity in the pre-nuclear interval sb (F[10, 90] = 3.113, $p < 0.001$). Again, speakers 5 and 6 do not differentiate between broad and narrow focus.

3.2.2. Contrast vs. Non-Contrast

No differences were found between the global measurements for contrast versus non-contrast, independent of the position of the nuclear accent.

4. Discussion and Conclusions

We investigated the prosodic realizations of information structure categories in Bulgarian. With regard to the difference between non-contrastive and contrastive focus, we observed that contrastive focus was marked more prominently than non-contrastive focus only locally and only in terms of vowel and syllable duration, when the CW occurs in the first half of the utterance. These results are not captured by a standard ToBI annotation.

With regard to the difference between broad focus and narrow focus on CW2, it was found that both local and global parameters were used. More specifically, narrow-focused syllables in CW2 were consistently realized with a longer duration, later peak alignment (but still early in the syllable), greater F0 excursions and higher energy than syllables with broad focus (local measures). This finding is not surprising, since all subjects but one used different pitch accent types to signal narrow vs. broad focus: (L+)H* vs. H+!H*/L*, respectively.

More important for the issue addressed in this study are the differences found in the global measurements. In agreement with results of previous research [1, 2, 6] no de-accentuation was found for narrow focus on CW2 in pre-nuclear position. Broad and narrow focus are not distinguished by accent type on CW1 (L*+H for both), nor is there a difference in global F0. However, the thematic, pre-nuclear interval (sb) in the narrow focus condition differs from the rhematic, pre-nuclear interval in the broad focus condition in terms of global measures. In responses with broad focus the interval preceding a focused syllable (sb) has a longer duration and a higher intensity than responses with narrow focus on CW2. This intensity difference is also found for the pre-nuclear CW1 vowel alone. Also, the interval following the nuclear accent has a lower intensity in responses with broad focus than responses with narrow focus on CW2. This finding is consistent with the observed post-nuclear vowel devoicing in broad focus conditions observed in [3].

To conclude, the all-important function of intonation, namely to transmit the relative weighting of information in speech communication, cannot be captured by a purely phonological description of realized accent types. Crucially, the IS-related patterns of phonetic prominence which are revealed in this study show a complex interplay between phonological categories and the local and global phonetic signal properties.

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