EXPANDING THE LIST OF PROSODIC PARAMETERS FOR DECLARATIVES, INTERROGATIVES AND EXCLAMATIONS IN RUSSIAN

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This paper examines the role of pitch peak alignment in the production of Russian one-word three-syllable declaratives, interrogatives and exclamations with the rising-falling pitch. The reported experimental study shows that the pitch peak occurs earlier in exclamations and declaratives (close to the accented vowel onset) and later in interrogatives (close to the accented vowel offset). A set of other prosodic parameters contributing to the differentiation of the three sentence types is identified. Implications for Russian intonation system are discussed.

1. Introduction

This paper investigates the alignment of pitch maxima in short declarative, interrogative and exclamatory utterances with rising-falling pitch patterns in Russian. The concept of tonal alignment relates to the "segmental anchoring of tonal targets" (Ladd, Faulkner, Faulkner, Shepman, 1999), i.e., to the exact location of the turning points of the pitch contour (pitch peaks, troughs, maxima and minima) in regards of the segmental string ('t Hart & Cohen, 1973; Bruce, 1977; Arvaniti, Ladd & Mennen, 1998; Arvaniti, Ladd & Mennen, 2006).

It has been observed that the alignment of pitch events has many important linguistic functions. For example, it contributes to word segmentation in French (Welby, 2006), differentiation of lexical tones in tonal languages (Xu, 1998, 1999, 2002) and to pitch accent differentiation in non-tonal languages including Dutch (Caspers & van Heuven, 1993), German and English (Grabe, 1998), Spanish (Prieto, van Santen & Hirschberg) and others (Arvaniti, Ladd & Mennen, 2006). In particular, alignment of pitch peaks has been shown to play an important role in disambiguating 'yes-no' questions and statements in a number of languages including Hungarian (Gosy & Terken, 1994), Neapolitan Italian (D'Imperio & House, 1997), Swedish (House, 2003) and Greek (Arvaniti, Ladd & Mennen, 2006). Very fine differences in the alignment of pitch peaks occurring in rising-falling contours have been detected in the production of statements and questions in Hungarian (Gosy & Terken, 1994) and Greek (Arvaniti, Ladd & Mennen, 2006). It has been demonstrated that these differences are employed by native speakers of these languages in identifying sentence types in perception (ibid).

In Russian, rising-falling contours are used in the production of statements and contrastive statements, 'yes-no' (polar) questions, exclamations and enumerations (Bryzgunova, 1977; Svetozarova, 1982). Phonologically, the rise-falls in statements and exclamations are typically classified as variants of falling contours, whereas rise-falls in questions and exclamations are described as realizations of rising contours (Bryzgunova, 1977; Nikolaeva, 1977; Svetozarova, 1982). In terms of their phonetic characteristics, however, all the

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above sentence types can have very similar rising-falling patterns, in particular in cases of short utterances (Svetozarova, 1982). Some perceptual experiments have suggested that the height and magnitude of the rising part of the contour are essential for differentiation between short (2-3-syllable) declaratives on the one hand and exclamations and interrogatives on the other hand, whereas enumerations have a smaller falling component as compared to other sentence types (Makarova, 1999, 2001). However, the parameters responsible for the disambiguation of exclamations and interrogatives remained unclear.

The current experimental study was designed to test the hypothesis that pitch peak alignment may be a parameter salient for disambiguating declaratives and exclamations on the one hand and interrogatives on the other hand in speech production in Russian.

2. Materials and methods

2.1 Materials and speakers

A list of 22 one-word three-syllable sentences of the [CVCVCV] phonemic structure with the lexical stress on the penultimate syllable was selected as the material for the study. Words with maximum number of sonorants in the [C] slots were preferred to prevent interruptions in the pitch contour, e.g., 'malina', *raspberry*. The respective segments are referred to as c1, c2, c3 (consonants of the first, second and third syllables), and v1, v2, v3 (vowels of the first, second and third syllables). The words were read by five female native speakers of Russian as a declarative, exclamation and a question.

2.2. Method

The digital recording was made in the recording sound-proof studio at 48KHz sampling rate and analyzed using ESPS Waves on a SUN workstation. F0 contours were obtained for all the data. The data were manually segmented. The analysis included measurements of the following points (primary parameters): segmental durations (ms), pitch height at the beginning and end of each segment (Hz), pitch height at the durational mid-point of each vowel (Hz), pitch peak height (Hz), pitch peak alignment (ms from the stressed vowel onset), pitch minimum in the last syllable (Hz), alignment of pitch minimum (ms from the final vowel onset). Twelve more parameters were computed to account for the general characteristics of the pitch contour movement: total interval of the rise, total interval of the fall, the ratio of the interval of the rise to the interval of the fall, rise interval in the pre-accented syllable, rise interval in the accented syllable, fall interval in the accented syllable, fall interval in the post-accented syllable, the ration of the rise interval in the pre-accented syllable to the rise interval in the post-accented syllable, as well as velocities of the total rise and fall, velocities of the rise and fall in the accented syllables.

Pitch peak alignment was measured in ms from the accented vowel onset and converted in relative units (r.u.) in regards of the vowel duration (ref. Figure 1 for the representation of the word structure and the measurement of pitch peak alignment).

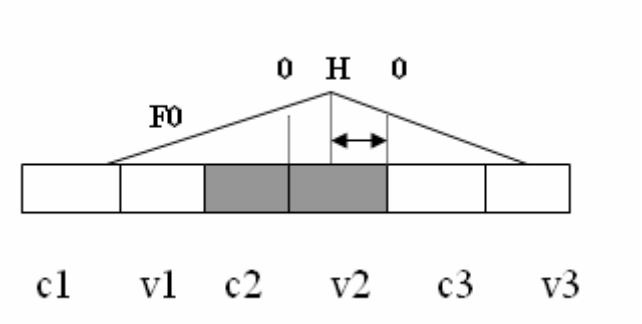


Figure 1. Measuring pitch peak alignment

2.3. Statistical analysis

Primary and computed parameters for the three sentence types were subjected to Univariate Analysis of Variance with SPSS 13.0 for Windows. Additionally, the Analysis allowed to check if any of the investigated parameters show subject-specific variability. In the analysis, the sentence type was selected as a fixed factor, and speaker as a random factor.

The analysis results are represented below in Table 1, which lists twenty two parameters displaying significant dependency on 'sentence type' factor in the decreasing order of significance (the effect is considered significant if p values are below 0.05). For parameters with a significant dependency on sentence type a subsequent *Student-Newman-Keuls (S-N-K) Post-hoc* procedure to determine whether significant differences exist in the mean parameter values across the three sentence types (i.e. between declaratives, interrogatives and exclamations).

3. Results

3.1. Pitch peak alignment and height in sentence type production

As can be seen from Table 1, the parameter of pitch peak timing (alignment) displays a highly significant effect of 'sentence type'. Post-hoc results indicate that the pitch peak occurs significantly later in interrogatives than in declaratives and exclamations. The alignment differences between declaratives and exclamations were insignificant for this sample.

In declaratives and exclamations, the pitch peak typically occurs on the average soon after the accented vowel onset (the mean values of 0.34 and 0.23 r.u. respectively), whereas in interrogatives, the pitch peak is achieved later, close to the accented vowel offset (0.92 r.u.). The average position of the pitch peaks in regards of the segmental string is further illustrated in Figure 2.

The parameter of pitch peak alignment also shows significant dependency on the speaker (Ref Table 1). Although the difference between earlier peak in declaratives and exclamations vs. later peak in interrogatives is common for all the speakers, the exact alignment of the peak may vary from the pre-accented syllable to half the length of the accented vowel in declaratives and

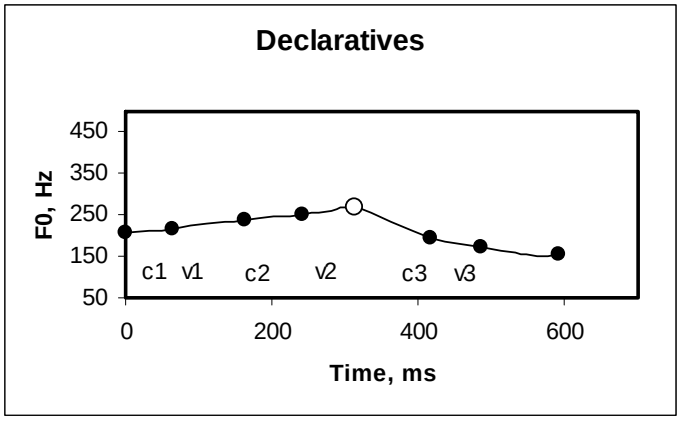
exclamations, and from late in the accented vowel to early in the postaccented syllable in exclamations.

Table 1
The effect of 'sentence type' and 'speaker' factors on phonetic parameters

N	phonetic parameters	p values	
		sent. type (df=2)	speaker (df=4)
	Maximum salience group (p<0.001)		
1	pitch peak timing	**0.000***	**0.013**
2	total fall velocity	**0.000**	0.828
3	fall interval in the pre-accented syllable	**0.000**	0.058
4	rise interval in the pre-accented syllable	**0.000**	0.053
5	rise interval in the accented syllable	**0.000**	0.592
6	rise interval/fall interval ratio	**0.000**	**0.015**
	Medium salience group (p<0.01)		
7	c2 onset frequency	**0.001**	0.143
8	v2 onset frequency	**0.001**	0.107
9	velocity of the fall in the accented syllable	**0.001**	**0.018**
10	fall interval in the accented syllable	**0.001**	**0.014**
11	v3 onset frequency	**0.002**	**0.001**
12	total rise velocity	**0.003**	**0.032**
13	total interval of the rise	**0.003**	0.138
14	c3 onset frequency	**0.004**	**0.044**
15	pitch peak height	**0.005**	0.197
16	total interval of the fall	**0.007**	0.155
17	fall interval in the post-accented syllable	**0.007**	0.328
18	velocity of the rise in the accented syllable	**0.007**	0.055
19	v1 mid-point frequency	**0.008**	0.123
	Low salience group (p<0.05)		
20	v2 duration	**0.018**	**0.01**
21	v2 mid-point frequency	**0.047**	0.309
22	v3 mid-point frequency	**0.050**	**0.000**

*Significant effects are in bold. The entries 0.000 indicate that p values are smaller than 0.001

The experiment demonstrates that the alignment of pitch peak contributes to the differentiation between Russian declaratives and exclamations on the one hand and interrogatives on the other hand.



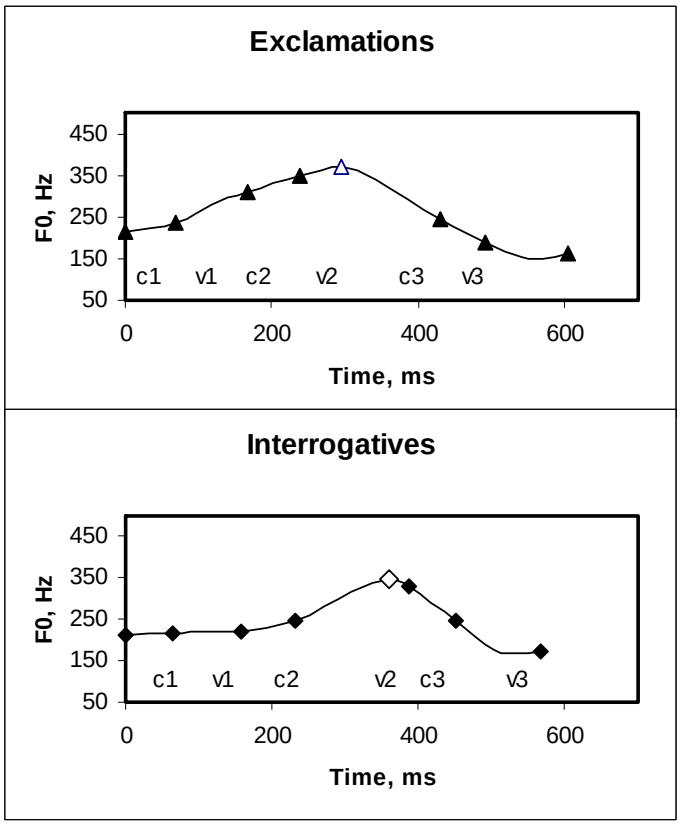


Figure 2. Average parameters of one-word declaratives, exclamations and interrogatives.

The Univariate Analysis of Varience showed that pitch peak height is significantly affected by the sentence type factor ($p<005$, ref Table 1). The Post-Hoc analysis demonstrates that declaratives have a lower pitch peak (266 Hz) than interrogatives (351 Hz) and exclamations (369 Hz), whereas the difference in pitch height between interrogatives and exclamations is not significant for these data.

3.2. Other parametric differences

An earlier pitch peak in declaratives and exclamations affects the values of other parameters used to describe the contours. The rising movement starts earlier in exclamations and declaratives, i.e., already in the pre-accented syllable (stretch from 0 to v1 in Fig. 2), as demonstrated by higher frequency values at v1 mid-point and c2 onsets (see Table 1). It should be noted here that the values for v1 mid-point and c2 onset frequencies are higher for declaratives than for interrogatives (even though insignificantly, see Table 1), and that there is an increase in pitch height from v1 mid-point to c2 onset for declaratives, but not for interrogatives. The earlier pitch peak in declaratives and exclamations also manifests in the decrease in frequency values from v2 onset to v2 mid-point and onwards in these two sentence types (7Hz in declaratives and 10Hz in exclamations) as opposed to interrogatives (where there is a 98Hz increase in frequency values from v2 onset to v2 mid-point). The earlier pitch peak in declaratives and exclamations also leads to an earlier completion of the fall in these sentence types: c3 ($\bar{x}_{decl}$ = 196.3Hz; $\bar{x}_{excl}$ = 241.6Hz) and v3 ($\bar{x}_{decl}$ = 173Hz; $\bar{x}_{excl}$ = 188.6Hz) onset values are lower for declaratives and exclamations than for interrogatives (c3 $\bar{x}_{inter}$ = 329.7; v3 $\bar{x}_{inter=}$ 246.5Hz). Also, the stretch from v2 mid-point to c3 onset shows a strong decrease in frequency values for declaratives (the difference in frequencies between these points is 49.6 Hz) and exclamations (98.4 Hz), but not for interrogatives (13.9 Hz). We also see that the fall interval in the post-accented syllable in declaratives and exclamations is smaller than in interrogatives ($\bar{x}_{decl}$ = 43.9Hz; $\bar{x}_{excl}$ = 96.2Hz; $\bar{x}_{inter}$ = 166.9Hz), which is another evidence of a later completion of the falling movement in interrogatives.

Interestingly, in interrogatives, the rise which is delayed until the beginning of the accented syllable, can be preceded by a small drop in pitch in the pre-accented syllable for some speakers.

Pitch movement intervals within the accented syllable are also partly reflective of the peak alignment: although the total interval of the rise does not differ significantly between interrogatives and exclamations (declaratives having a significantly smaller interval), and the pitch rise within the pre-accented syllable in exclamations is significantly greater than in interrogatives, the opposite is true of the pitch rise in the accented syllable, i.e., in the accented syllable, the pitch rise is greater in interrogatives than in exclamations.

The total interval of the fall is the greatest in exclamations, medium in interrogatives and the smallest in declaratives. In the accented syllable, however, exclamations also have the largest fall interval, but declaratives have a greater fall interval than interrogatives.

4. Discussion

4.1. Pitch peak alignment in Russian sentence type disambiguation

The data in the study suggest that pitch peak alignment is a salient feature in Russian sentence type disambiguation, similarly to Greek, Hungarian and other languages (Arvaniti, Ladd & Mennen, 2006). It is possible to expect that in particular in cases of relatively little prosodic variability (similar pitch peak

heights and rising-falling contours in Russian exclamations and interrogatives) additional parameters (such as alignment) are needed to perform disambiguation.
It needs to be determined in future perception experiments whether Russian speakers utilize these distinctions in perception.

There appears to be a trend re-current across unrelated languages where rising tones are characterized by the late alignment of the pitch peak (close to the accented vowel onset), whereby the onset of the rise is often found in the beginning of the accented vowel. This phenomenon was observed for Mandarin Chinese lexical rising tones (Xu, 1998), rising pre-nuclear accents in Dutch and Greek (Ladd, Mennen, Schepman, 2000), nuclear rising accents located in different phrasal positions in Spanish (Prieto, Santen, Hirschberg, 1995), rising/rise-falling nuclear accents in interrogatives and non-final phrases (enumerations) in Russian (Makarova, 1999, 2000). It seems logical that since the achievement of the high pitch level and/or of a great magnitude of the rising pitch movement may be the 'target' or 'goal' of the rising tone, most of the accented (or lexical tone carrier) syllable is 'given over' to the realization of the rising pitch movement. The location of the 'low' onset of the rise movement in the beginning of the accented (tone carrier) syllable serves to emphasize the 'reference point' for the rise.

4.2. Some implications for Russian intonation system analysis

If adhering strictly to Pierhumbert's (1980) notation, which singles by star only one pitch height (the target of the accented syllable) and disregards pre-accented syllables, then the contours can be described as follows (with British English contour notation given for comparison):

declaratives	H*...L...L%	low pre-head+Mid fall
exclamations	H*...L...L%	low pre-head+High Fall+ low tail
interrogatives	L+H*...L...L%	low pre-head+Rise-Fall+ low tail

It has been often discussed that Pierhumbert's notation is very confusing when it comes to differentiation of the types of falling and rise-falling movements (Ladd, 1996). In particular, it is difficult to render the idea of a 'medium' fall. It is also challenging to decide what is the 'target' of the accented syllable, since there is a rising and a falling movement in the accented syllable.

Another possibility to describe these contour distinctions in ToBI approach is to represent each contour as a LHL sequence:

declaratives	L+H* L%	
exclamations	L+H* L%	
interrogatives	L*+H L%	or (LH)* L%

This again, however, leaves us with a problem of differentiating between two different heights (lower for declaratives and higher for interrogatives and exclamations).

It appears at the intuitive level (although it goes contrary to the customary ToBI notation), that all the three sentence types have two tonal targets to achieve. For declaratives and exclamations, these are H (or M for declaratives, if M level were allowed for) target in the beginning of the accented syllable and the L target in the end of the accented syllable with L% spreading into the post-accented syllables. For interrogatives, there are L and H targets to be achieved within the accented syllable, whereby L target can be also achieved in the pre-accented syllable, and H target can be achieved early in the post-accented syllable (probably because of a certain inertia of the voice source). The achieved H target is followed by a L% boundary tone, if post-accented syllables are present.

Although it will be, perhaps, tempting to suggest that in interrogatives, the post-accented syllable becomes crowded with the late target (peak) and the boundary tone, it is impossible to pursue this topic without performing further experiments with varied syllabic structures and varied numbers of pre-accented and post-accented syllables. According to Russian intonation descriptions (e.g., Svetozarova, 1982; Nikolaeva, 1977), and from the author's experience with the analysis of Russian speech intonation, post-accented syllables in all the three investigated sentence types will have a L% boundary tone (although in interrogatives the peak can actually be achieved in the first post-accented syllable), but it needs further evidence. It is also important in future studies to trace the distribution of the falling movement across the post-accented syllables in interrogatives with different numbers of post-accented syllables.

Moreover, it would be necessary to compare the contours investigated here with other contours possible in these sentence types. In particular, the 'singling out' or 'contrastive' declaratives investigated here need to be compared with Russian low falling declaratives which start with relatively high pitch pre-accented syllables and have a low falling pitch movement in the accented syllable. It would be also interesting to perform a production experiment followed by a perception experiment which will address the comparison of interrogative contours with the ones found in two types of enumerations: rise-falling enumerations (found in casual conversation and resembling interrogatives in pitch pattern and possibly peak alignment) and low-rising enumerations (found in formal speech and having a rising pitch movement starting in the beginning of the accented syllable).

4.3. Prosodic parameters and redundancy

Languages like English or German have the strict word order and employ lexical and grammatical markers of sentence type (auxiliaries plus word order inversion) still additionally mark their 'yes-no' questions with a rising pitch contour. On the other hand, language like Russian and Hungarian with a loose word order and no interrogative markers present (whereby a statement in speech can only be differentiated from a 'yes-no' question by means of intonation) use rise-falls in a few sentence types. This creates the need for additional clues to disambiguate them (such as pitch heights, ratios of pitch movements and pitch peak alignments). It appears to be a mysterious case of redundancy for the first type of languages and extravagance for the other.

Conclusion

The experiment reported in this paper indicates that along with a number of other languages, Russian employs pitch peak alignment for differentiating between phonologically different types of contours with similar phonetic realizations (phonetic rise-falls representing phonological rises and falls). These pitch peak alignment differences are used for serving the expression of different sentence types (declaratives and exclamations with an earlier pitch peak and interrogatives with a later pitch peak). Additionally, pitch height allows the differentiation between declaratives (with a lower pitch peak) and exclamations (with a higher pitch peak). Further experiments are on the way to prove the relevance of the parameter on the listeners' perception of sentence type. Pitch event alignment may need to be considered as a candidate for universal tendencies in the intonation and prosodic systems of the world languages.

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