Speech Rhythmic Patterns of the Slavic Languages

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Abstract. The comparative experimental acoustic study of the subjective and objective characteristics of the rhythmic organization of speech was carried out on the material from three Slavic languages, i.e. Czech, Bulgarian and Russian. The present study has supported the validity of the hypothesis on the existence of a hierarchy of factors that determine the rhythmic patterns in the Slavic languages. The results of the acoustic analysis have revealed the phonetic specificity of RS and RPS, which is determined by the phonetic structure of stress in RS, realized in the studied languages by different means: definite combinations of prosodic features of vowels at the RS boundaries in Czech speech, a dynamic component in Bulgarian and a spectral as well as a temporal component in Russian.

Keywords: Rhythm; rhythmic structure; syntagma; rhythmic patterns; segmentation; hierarchy of factors.

1 Introduction

Rhythm is an important manifestation of the specific peculiarities of the perceptive and acoustic (prosodic, in particular) speech structure in various forms of speech production [5,11, etc.]. In the present study, rhythm of spoken prose is not understood as a rigidly fixed sequence of particular speech segments and the auditory perception of this sequence, which is characteristic for the verse rhythm [2,13,16, etc.], but as the specific distribution of these segments (e.g., of sounds, syllables, rhythmic groups and so on) in time as well as their phonetic (qualitative and quantitative) expression (see also: [6]). Such an approach to the rhythm of speech or the spoken language realized text makes the problem particularly complex and requiring thorough examination.

The comparative experimental acoustic study of the subjective and objective characteristics of the rhythmic organization of speech was carried out on the material from three related languages, i.e. Czech, Bulgarian and Russian; the experimental material included journalistic texts[1] (newspaper articles, papers and talks on various cultural, economic and political subjects) as well as scientific and technical texts (technical documentation, manuals etc.) read by native speakers of the languages in question; part of the research done was the first attempt at a comparative study of the rhythmic patterns of Czech utterances taken from journalistic, technical and fiction prose texts; besides the auditory analysis of prosodic characteristics (fundamental frequency, duration and

[1] The style of journalistic articles (= political essay style) is characterized by the presence of social and political terms and by being logical, emotional, evaluative and agitating.

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intensity), the study of rhythmic patterns in the three languages included spectral analysis of stressed vowels; the processing of experimental data obtained involved statistical means; the spectral analysis of stressed vowels was carried out by means of computer program Sound Forge (Sony Creative Software); the proposed description of rhythmic patterns of speech is the first one to use not only phonetic data but also data obtained as a result of a grammatical parsing of rhythmic units.

In the description of the rhythmic patterns of utterances the basic unit was defined as a rhythmic structure (RS)[2], understood as one or several words (both notional and auxiliary) united by a single word stress [10]. Unlike the related term phonetic word, the term rhythmic structure emphasizes the fact that the given unit belongs to the system of rhythmic units and allows to present it as a structurally organized sound and syllabic complex [14,15]. In the last few years linguists have been particularly interested in studying rhythmic units and the analysis of the details has proved the rightness of using rhythmic structures as basic units of rhythm, because they convey a certain meaning and at the same time carry certain prosodic information. Rhythmic structures are realized relatively discretely within utterances and can be isolated from the context; they can function independently (as a word-phrase) on one side and act as part of a connected text on the other, performing certain rhythmic and semantic functions. In speech communication, RS are both units of speech production and speech perception [7,8].

The syntagma[3], understood as "a phonetic unity, expressing single notion in the process of speech-thinking" [12], was taken as a larger unit on which the analysis of the speech material was based. Many phoneticians believe that a syntagma is a unit which is both semantic and formal in character, one of its most important characteristics being the ability of forming an intonation and semantic unity. Within a single syntagma there can be one or several RS expressing well-formed semantic notions that can be identified both by the auditors and at the level of acoustic experiments. Among the main parameters characterizing the syntagma we considered the number of RS and syllables within a syntagma, the order of RS in it, which reflect various types of *rhythmic patterns of syntagmas* (RPS).

The main assumption underlying our research was that closely related languages may be characterized by different means of the phonetic structuring of speech rhythm, which is not only related to the specific prosody of the languages in question, but also to the specific grammar of the latter. Besides the above main assumption we formulated some minor assumptions of a less general character. Thus we assumed that the structuring principle does not only underlie the organo-genetic, systemic and dialectal phonetic phenomena, but also the stylistic differentiating phenomena at the level of structural and rhythmic organization of speech. Furthermore, we believed that, as compared to Czech,

[2] For example, 3/1. The numerator of this fraction corresponds with the number of syllables of the RS (classes), whereas the denominator indicates the localization of the stressed syllable within the RS (types).

[3] In linguistics, a syntagma is an elementary constituent segment within a text. Such a segment can be a phoneme, a word, a grammatical phrase, a sentence, or an event within a larger narrative structure, depending on the level of analysis. Syntagmatic analysis involves the study of relationships (rules of combination) among syntagmas (see: [3])

Russian and Bulgarian have more features in common in their rhythmic organization (due to, e.g., various stress patterns, the reduction of unstressed vowels and so on).

Detailed study and understanding of various conceptions of rhythm has made it possible to conclude that at present works based on a comparative study of closely related languages are of great theoretical and practical value [4,6, etc.] because it is in closely related languages that we find ”imaginary similarities” [9] that are more difficult of overcoming than ”inconspicuous similarities” in unrelated languages.

Modern experimental speech studies have supported the presence of rhythm in spoken language. Rhythm is a result of a combination of physiological factors of speech production, of the specificity of the sound and syllable inventories and of the whole phonetic structure as such. The rhythm of prose interpreted here as a distribution in time of specific qualitative and quantitative features of various phonetic units is considered to be an intrinsically organized hierarchic structure. The basic level in the hierarchy of rhythmic segmentation of speech (the syllable rhythm level) is directly related to the level of syntagmatic and phrase rhythm, which in its turn is related to semantics and syntax. The rhythmic component is organically included in intonation. All levels are closely related and form a wholesome structure.

When studying the rhythm of speech, it is possible to use various basic units, depending on the character of stress patterns in different languages, different understanding of rhythmic segmentation and approaches to the problem in question (whether it is phonetic, physiological or any other). As mentioned above, in the present study we used RS as a basic unit.

2 Methods, Analysis and Results

In the course of the study, test texts (forty texts for each language) were recorded in an echo-free chamber by native speakers with a normative manner of pronunciation (15 speakers for each of the languages in question). In three months' time after the recording the same subjects were used for the auditory analysis of the texts and were asked to listen to the whole recorded material, to correct pronunciation mistakes made and to read once more the same texts but correctly. The next stage of the auditory analysis envisaged identification of stressed syllables and segmentation of spoken texts into minimal speech fragments, i.e. sequences of words united by a single stress. The auditory analysis was carried out on the individual basis binaurally and repeatedly according to the two programs: a) recording of the current phrases of the texts and their subsequent segmentation into RS and syntagmas; b) segmentation of the reproduced recording into minimal speech fragments, united by a single stress, relying on the text typed without capitals, punctuation marks and spaces between words, i.e. as a continuous string of letters.

Regarding the number of syllables in RS, we have found that two- and three-syllable RS are predominant in Czech texts, two-, four- and five-syllable RS in Bulgarian texts, and two-, three- and four-syllable RS in Russian texts.

As regards the most frequent structures, journalistic, scientific and technical texts differ from fiction prose (in the former the number of RS with more than three components is bigger than in the latter), Czech was found to have a more specific distribution

of RS when compared to Russian and Bulgarian, and a more contrasting distribution of RS in terms of their frequencies for the two types of text (journalistic, scientific and technical on one side, and fiction prose on the other); for Bulgarian this distribution was found to be less contrasting.

The comparison of the rhythmic patterns of syntagmas (RPS) with due account of the RS specificity has shown the following: in Czech the most frequent RPS consist of two RS(3/1 3/3; 4/1 3/1; 2/1 4/1 and so on), of three RS and four RS (3/1 3/1 3/1; 3/1 4/1 6/1; 2/1 3/2 4/1 and so on). In Bulgarian the picture is different; the very type of RPS becomes different in syntagmas consisting of two RS, while in syntagmas consisting of three RS the pattern is like in Czech (2/1 3/1 2/2; 3/2 3/1 2/1; 4/2 4/3 4/3 and so on). In Russian, among the most frequent RPS we find those consisting of two RS (3/2 2/1; 3/2 3/1; 3/3 3/2 etc.) and of three RS (2/1 3/1 3/2; 2/1 3/2, 5/3; 2/1 1/1 5/2 etc.).

The least frequent syntaqmas in Czech are those consisting of nine RS, in Bulgarian those of eleven and twelve RS, in Russian those of nine, ten and twelve RS.

Regarding the number of syllables in syntagmas, we have found that in Czech two-RS syntagmas the average number of syllables is 7.6 and in three-RS syntagmas 10. In Bulgarian the figures are 7 and 12.6, in Russian 7 and 9.9 respectively. In the languages in question two-RS syntagmas are prevailing. Russian and Bulgarian are characterized by a greater frequency of three-RS syntagmas. Therefore in these three languages two- and three- component RPS can be considered the nucleus and the other RPS the periphery of the rhythmic structure.

Another point of interest was to see whether there were any trends in location of RS at the beginning and at the end of syntagmas. We proceeded from the assumption that rhythmic specificity of languages is determined not only by the predominant classes and types of RS, but also by their preferential location in syntagmas in which the beginning and the end (the first two and the last two RS) are presumably marked positions. The data obtained allow to present a Czech syntagma in the following schematic way:

3/1 2/1 ... n/n ... 2/1 3/1

A Bulgarian syntagma can be represented as follows:

n/2 (n/3; n/1) n/2 (n/3; n/1) ... n/n ... n/3 (n/2; n/1) n/3 (n/2; n/1)

The corresponding pattern for a Russian syntagma looks as follows:

n/2 (n/3; n/1) n/3 (n/2; n/1) ... n/n ... n/2 (n/3; n/1) n/2 (n/1; n/3)

The above considerations allow us to assume that the rhythmical structure of a language is determined, to a large extent, by its grammar. The variety of RS in analytic languages is the result of a wide use of combinations of auxiliary words and the notional ones, which supports our data for Bulgarian, the grammar of which is characterized by the analytic type of inclinations of nouns and pronouns. For synthetic languages like Russian, the specificity of RS is primarily explained by the variety of flexion forms in combination with conjunctions, propositions and so on. We have nearly the same picture in Czech, too. Therefore, the rhythmic peculiarities of languages do not only depend on their prosodic factors but also on the specificity of their grammars.

Another of our objectives was to see if there were any changes in timing, fundamental frequency and intensity within RS and RPS in the three languages considered. The following parameters were analyzed: duration (absolute total duration of RS, relative normalized total duration of RS, absolute vowel duration in RS, relative vowel duration in RS, mean vowel duration in syntagmas and so on); intensity (total intensity of vowels and sonorants in RS, maximum intensity of vowels and sonorants in RS); fundamental frequency (mean values of fundamental frequency for vowels and sonorants within RS, the range of fundamental frequency within RS, the range of fundamental frequency within syntagmas, the ratio of the fundamental frequencies for vowels at the boundaries between RS and others).

The analysis has revealed that in the flow of Czech speech RS are marked at the beginning and at the end of the structure but by various prosodic means: a positive or negative interval in the intonation at the boundaries of RS (in 75% of the cases regarding of all types of boundaries), a decrease in intensity at the end of RS (76%) and an increase in the duration of the final vowel or sonorant in RS (50%). There are two regularly marked positions in Czech, viz. the initial and the final ones. These positions seem to constitute a prosodic framework which is perceived aurally.

In Czech scientific and technical texts as well as in fiction prose realization of syntagmas is further characterized, as a rule, by an equally intensive markedness of syllables. The values of fundamental frequency tend to be monotonous. We also considered the timing of RS and of stressed vowels in RS. It should be noted that duration, fundamental frequency and intensity of RS in scientific and technical texts vary in a more narrow range than in fiction prose.

For Bulgarian RS we have established two types of features, common for the various types of texts and specific ones. In the first case we have a stable acoustic markedness of the stressed vowel by all prosodic means, but in the first place by duration and intensity, while in the second one we have a different contribution of these means. A greater dynamic range on stressed vowels of RS and a greater duration difference between stressed and unstressed vowels in RS make journalistic texts sound more expressive than scientific and technical texts. This is also supported by a wide range of changes in fundamental frequency (110 semitones for newspaper articles and 15 semitones for scientific and technical texts).

Comparison of the total duration of each RS within a syntagma has revealed the absence of RS isochronism in Bulgarian, which is a striking contrast to Czech. Bulgarian is also characterized by a greater degree of intonation variance and a wider intonation range than Czech. Stress patterns are also different in the two languages; in Bulgarian the maximally stressed vowels are those that bear primary stress. RS stress patterns are different in the two languages, too; in Bulgarian the RS stress is maximum in value and coincides with the lexical stress in a syllable bearing primary stress, while in Czech it is observed on the transition segment from the final vowel of one RS to the initial vowel of the subsequent RS. As already mentioned above, Czech speech flow is characterized by a prosodic markedness of the beginning and the end of RS; in Bulgarian regular prosodic features of this type are not observed.

It can be stated that for the two types of texts prosodic markedness is characterized by the same trend: greater markedness of RS in newspaper articles as compared to scientific and technical texts.

Regarding RS within syntagmas in spoken Russian, their duration varies considerably and depends, to a great extent, on the number of syllables in RS. This factor determines the total duration of RS to a greater extent than the position.

Comparison of the prosodic characteristics of RS in the three languages was carried out taking into account the following parameters: duration of all vowels in the syntagma (in percent), average duration of vowels, total duration of RS, number of vowels and syllables per unit of time, mean syllable duration, total intensity of RS, range of fundamental frequency across the syntagma, interval between fundamental frequency at the boundary between RS, and others.

In terms of total duration of vowels in the syntagma, the three languages are characterized by the following figures (see Table 1).

Table 1. Total duration of vowels and consonants in the syntagma (in %)

	Duration of vowels	Duration of consonants
Bulgarian	36	64
Russian	43	57
Czech	48	52

These data show that in the languages in question vowels account for a less share of the total speech flow than consonants. The minimum vowel duration is found in Bulgarian and the maximum one in Czech while Russian is somewhere in an intermediate position in this respect. Czech is characterized by the smallest ratio of the vowel to consonant duration.

Concerning average vowel duration, we can say that Russian has the highest values of this parameter (average $\overline{t_v} = 80$ ms). Bulgarian and Czech do not differ in this respect (average $\overline{t_v} = 60$ ms). In other words, spoken Russian is the slowest of the three.

Comparison of mean syllable duration reveals that the maximum mean value of syllable duration is found in Russian (average $\overline{t_s} = 205$ ms) and the minimum one in Bulgarian (average $\overline{t_s} = 137$ ms) while in Czech this parameter is intermediate in value (average $\overline{t_s} = 160$ ms). These data show that the average rate of spoken Russian amounts to approximately 5 syllables per second, of Bulgarian to 7 and of Czech to 6 syllables per second respectively. We may say that Bulgarian speech is the fastest and Russian speech the slowest, Czech being in an intermediate position in this respect.

As regards the intensity of stressed vowels in RS, Russian differs from the other two languages, the latter having a lower intensity of stressed vowels than the former. This testifies to a higher energy level of spoken Russian.

The three languages differ in terms of fundamental frequency, too. Across the phrase it varies in a wider range in Russian (up to 8 semitones), and in a more narrow range (up to 3 semitones) in Czech, Bulgarian being here in the intermediate position with values of up to 5 semitones.

For each sample of spoken texts the average total duration of RS was calculated, the average figures being $\overline{t_{\sum RS}} = 654$, 550 and 517 ms, respectively for Russian, Czech and Bulgarian. The average duration of RS varies from minimum in Czech to maximum in Russian. The values of average RS duration in Czech and Bulgarian are similar and not so high as in Russian, which enables us to state that the fragmentation of Czech and Bulgarian speech into RS is more detailed than in Russian.

Comparing RS in the languages concerned has made it possible to characterize spoken Czech as having a relatively narrow intonation range, with a minimum of changes in speech melody, a moderate level of energy content, a detailed fragmentation of syntagmas into RS (up to 7), a moderate speech rate and a shift of the 'gravity centre' in pronunciation onto the phonologically long vowels and sonorants, which leaves the impression of a rhythmic syncope. Spoken Bulgarian can be characterized as having a moderate intonation range, moderate changes in the intonation curve, moderate energy content, uniform fragmentation of syntagmas into RS (on the average 5 RS in a syntagma), a fast speech rate and reliance in terms of timing on consonants. The corresponding parameters obtained for Russian show that compared to Bulgarian and Czech, Russian speech is characterized by a maximum intonation range, a considerable amount of changes in the intonation curve, maximum energy content, uniform fragmentation of syntagmas into RS (on the average, from 5 to 7 RS per syntagma), a slow speech rate, the duration of consonants and vowels being nearly the same.

Each of the languages has certain acoustic features that make it possible to identify RS in the speech flow. Both vowels and consonants at the RS boundaries are characterized by definite acoustic features. In Russian, duration can be regarded as a parameter having the greatest information content in terms of the speech flow segmentation into RS. Maximum intensity and the rate of fundamental frequency changes can be regarded as complementary in this respect. In Czech which relies heavily on vowels and sonorants, duration is also an informative parameter. The duration of sonorants at the final position in RS considerably exceeds that at the beginning of RS before a vowel. Similar results were obtained in the acoustic segmentation of Bulgarian speech: duration, rate of fundamental frequency changes and intensity have been found to be indicative of RS boundaries.

The description of stressed vowels in RS would have been incomplete if their spectral characteristics had not been considered. The more so since prosodic features alone cannot determine the stress of a vowel. Therefore we thought it necessary to undertake a comparative analysis of stressed vowels in the languages in question. To obtain a more detailed description of the phonetic realization of RS, some fragments of the test texts were analyzed spectrally by means of computer program Sound Forge (Sony Creative Software). The results for Czech have shown differences for phonologically long and short stressed vowels. Thus, for example, average F1 and F2 of stressed vowels and average F1 and F2 of the corresponding phonologically long vowels differed not only quantitatively but also qualitatively. For example, the distribution of average F1 and F2 of phonologically long vowels shows that their articulation tends to be more frontal. In Czech post-stress and stressed vowels (outside the factor of phonological length) do not differ qualitatively.

For the Bulgarian vocalism the comparison was carried out on a different basis; we analyzed the spectra of stressed and corresponding unstressed vowels. The results have shown that unstressed vowels are closer than the stressed ones. Their articulation is characterized by a smaller jaw opening and restricted advance of the tongue to the front. Unstressed vowels in Bulgarian differ from the stressed ones both quantitatively and qualitatively. The spectra reveal a fuller realization of stressed vowels compared to unstressed ones as the latter are characterized by a considerable articulatory reduction in terms of both quantity and quality. As regards Russian, the results obtained with a special device for formant analysis have supported data obtained earlier by other researchers: stressed vowels are characterized by specific qualitative features.

The results obtained give us an insight into the nature of accent in the languages in question and therefore, into their specific rhythmic organization. Thus in Czech the qualitative characteristics of stressed and unstressed vowels in RS do not differ, they are characterized by the same degree of tenseness and the same duration. This is not true of the phonologically long vowels that are marked both quantitatively and qualitatively. On the whole, such a distribution affects the rhythmic organization of Czech which is characterized by the absence of vowel reduction, the identity of qualitative and quantitative characteristics of stressed and unstressed vowels and the markedness of phonologically long vowels. Such a spectral and temporal structure of vowels in Czech words together with the psychological fixation of the speaker and the listener on the first syllable of the word explain the specific rhythm of Czech speech which is in sharp contrast to that of Bulgarian and Russian where stressed and unstressed vowels differ considerably both qualitatively and quantitatively, phonologically long vowels are lacking and stress is free and mobile.

In conclusion we would like to underline the fact that modern typological language studies are characterized by the three main directions of search for universalities, for types and for individual specificity. The present study was carried out along the lines of this concept to solve the above mentioned tasks. We considered RS as a basic universal feature of rhythm serving as a link between languages with free and fixed stress.

The auditory analysis of journalistic, scientific and technical texts as well as that of fiction prose has revealed the specific features of the rhythmic structure of spoken Czech, Bulgarian and Russian. In terms of RS, no striking stylistic differences have been found within individual languages. We can only conclude that different types of texts are characterized by regrouping of RS classes and types. The study has provided another proof of the regularity observed earlier by other researchers that in Slavic languages there is a predominance of two-syllable RS with the stress on the first syllable. We have shown that three- and four-syllable RS are also quite frequent in the languages under consideration. The bulk of all RS is represented by those that contain from two to four syllables. As regards the number of RS per syntagma, we can conclude that in the three languages the nucleus is represented by syntagmas with three RS, while those containing only one RS or more than three lie on the periphery.

The frequency of RS with respect to their morphological composition is governed by certain laws intrinsic, for example, to Slavic languages. In this respect it is crucial whether the language is synthetic or analytical, because this fact determines the structure of RS and, consequently, the specific rhythm of utterances. Differences in style

may also affect the prevailing grammatical composition of RS. The latter factor does not exert, however, as considerable an influence as the language grammar does.

The results of the acoustic analysis have revealed the phonetic specificity of RS and RPS, which is determined by the phonetic structure of stress in RS, realized in the studied languages by different means: definite combinations of prosodic features of vowels at the RS boundaries in Czech speech, a dynamic component in Bulgarian and a spectral as well as a temporal component in Russian. All these features are responsible for specific combinations of qualitative and quantitative parameters that shape the rhythm of spoken prose in the languages considered. RS are identified not only on the basis of stress but also on the basis of the acoustic features of boundaries between RS that are present in the speech flow but frequently deny identification because they are weakly expressed acoustically.

3 Conclusion

From the point of view of an integral perception of rhythm in Czech, it can be represented as a dot-and-dash line where dots correspond to equally stressed vowels (syllables) and dashes to specifically emphasized sounds (syllables) that are a result of phonological length, wide vowels, syllable-forming sonorants and RS final position. The corresponding picture of Bulgarian speech rhythm will be a dotted line where dots represent vowels (syllables) with a minimum quantitative expression. Russian speech which is characterized by a longer duration of vowels (syllables) can be represented as a dash line or a solid wave-like curve. The assumption of a greater similarity of Bulgarian and Russian as opposed to Czech with respect to a number of parameters has been supported by experimental phonetic data.

Therefore, the present study has supported the validity of the hypothesis on the existence of a hierarchy of factors that determine the rhythmic organization of utterances: the underlying factor is found in stress, followed by grammar which affects the speech rhythm indirectly, through various combinations of parts of speech, forming proclitics and enclitics, and finally by stylistic peculiarities though the latter exert but a weak influence on rhythm.

The specific tasks of modern studies, related to the comparative analysis of RS classes and types (i. e. classes of RS are based on the number of syllables, types of RS on the localization of the stressed syllable within RS) as well as of RPS types in languages, their prosodic markedness and perceptive specificity, allow to solve the main problem of determining the prosodic organization of rhythm in the contrasting aspect. It should be noted that in some cases in sufficiently developed rhythmic conceptions impede the perception mechanisms. The point is that word perception and decision-making about their meaning may go by two ways. The first way can be described as follows: each segment in the chain of sounds is consequently identified by the listeners with some phoneme. In this case every the segment elements should contain phonetic information sufficient for such phonemic identification. There can be another way when the listener relies, for example, on the rhythmic structure rather than on the segment units. If this is so, the rhythmic structure becomes the basis for word recognition process. Such a situation is most frequently observed when articulation is incomplete, primarily in

colloquial speech and the listener tries to guess the meaning of words relying on their integral properties.

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