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THE TYPOLOGY OF DYNAMIC AND MELODIC SYLLABLE MODELS FOR GERMANIC AND SLAVIC LANGUAGES

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Abstract: Prosodic characteristics and types of the rhythmic patterns of words are taken into consideration. The results represent the most stable generalized types of dynamic and melodic models for Germanic and Slavic languages. This research allows us to describe features, which are most important for correct syllabic coarticulation and rhythmic realization of spoken utterance: number of intensity peaks in a vowel; rate of increase – decrease of intensity values; location of transitional phases; degree of their proximity to the peaks of vowel intensity; character of changes of a melodic curve in the whole structure of syllable and its constituents.

Keywords: typology, rhythm, model, syllable, duration, fundamental frequency, intensity, Germanic, Slavic.

1. DYNAMIC AND MELODIC SYLLABLE MODELS FOR GERMANIC LANGUAGES

1.1. The role of typology researches on the domain of syllable phonetics

The term 'typology' has a number of different uses, both within linguistics and without. The common definition of the term is roughly synonymous with 'taxonomy' or 'classification', a classification of the phenomenon under study into types particularly structural types. This is

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the definition that is found outside of linguistics, for example in biology, a field that inspired linguistic theory in the nineteenth century.

The broadest and most unassuming definition of 'typology' refers to a classification of structural types across languages. In this definition a language is taken to belong to a single type, and a typology of languages is definition of the types and an enumeration or classification of the languages into those types. We will refer to this definition of typology as typological classification. In this case typology has to do with cross-linguistic comparison of some sort. A more specific definition of 'typology' is that it is, the study of linguistic patterns that are found cross-linguistically, in particular, patterns that can be discovered solely by cross-linguistic comparison. The classic example of typology under this definition is the implicational universal. There is a final, still specific definition of «typology». On this view, typology represents an "approach" to the study of language that contrasts with prior approaches, such as American structuralism and generative grammar. In this last definition, typology is an approach to linguistic theorizing, or more precisely a methodology of linguistic analysis, that gives rise to different kinds of linguistic theories than other "approaches". Sometimes this view of typology is called the «Greenbergian» as opposed to the «Chomskyan». This view of typology is closely allied to functionalism, the hypothesis that linguistic structure should be explained primarily in terms of linguistic function. Typology in this sense is often called the functional-typological approach. The «Chomskyan» approach contrastively titled formalism.

The first question that may be asked of typology is, what is the role of cross-linguistic comparison. It is possible to argue that cross-linguistic comparison places the explanation of intralinguistic phenomena in a new and different perspective. We will use the term «typology» to refer to the subdiscipline: cross-linguistic comparison of syllable and rhythm phenomena. The primary purpose of this paper to discuss the kinds of cross-linguistic patterns that have been discovered and the methodological and empirical issues raised by the study of these patterns.

The fundamental characteristic of typology is linguistic analysis. To day a number of linguists has turned to using spoken textual data for analysis. This has the advantage of being data of actual spoken language, unfiltered by artificial elicitation situations, or by informants self perceptions. Also, connected speech provide quantitative data, which play an important role in typological analysis. Typological classification is the process of describing the various linguistic types found across languages for some parameter, such as a number of speech segments. The usual procedure for initiating a cross-linguistic comparison of phonetic phenomenon for the purposes of a typological analysis is to survey the range of structures used for the phenomenon in question. These structures (in this case syllables) are called *types or strategies*. Also, the typology of art of syllable segmentation displays practically the full range of segmentation strategies.

The process of syllable segmentation of spoken image is a basis of our typological description. It is necessary to distinguish three kinds of speech segments: speech production segments, speech perception segments and speech acoustic segments. In all this cases the process of such segmentation includes simultaneously two phenomena: *continuity and discontinuity*. The aim of segmentation could be characterized as description of speech continuum with special symbols which correspond to a finite number of compound parts (states). For example: a) on

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the domain of speech production - the activity of voice source, duration of this activity, the activity of tongue, velum and lips muscles, beginning and ending of functioning of oral and nasal cavities, distribution of tensness and laxness of muscle activity; b) on the domain of speech perception - auditory segmentation of speech wave with orientation toward the modification (rising and falling) of fundamental frequency, auditory reaction on modification of spectrum energy, and duration of time intervals; c) on the domain of speech acoustics - presence or absence of fundamental frequency, presence or absence of noise, low spectrum energy, high spectrum energy, location of noise on the spectrum scale, duration of noise, intensity of noise, duration of pause and so on.

All these speech segmentation characteristics correspond with articulatory base of each language, phonological constraints, linguistic rules of utterance construction and style (genre and register) of speech communication. From this point of view it would be necessary to define and to describe all types of speech segments and its classification for different languages of the world, the groups of languages with identical features of segments, similar features and unsimilar ones of different languages which can be near or not near from genetic point of view. The description of speech segment systems of different languages on the domain of spoken language special for speech production, speech perception and speech acoustics, the classification of this systems and subsystems, kinds of corresponding relations between them are very important for theory of language and applied linguistics: speech analysis and synthesis, automatically speech recognition, language teaching, leaning and acquisition. In this case there is opportunity to find and to describe types of syllable segmentation, its acoustic characteristics, to classify this data and to define some universals on this domain. In this sense we propose to distinguish three types of speech segments: micro – (subsound, sound, syllable), media – (phonetic word, or rhythmic structure) and macrosegments (syntagma, phrase). It is possible to mark out the specific branch of experimental phonetics – the *segmentology,* which has to include its own object, a set of specific approaches, main purpose of research and area of application of results.

1.2. The main hypothesis of research

The present research is the first experimental phonetic study of the syllable structuring of speech in Germanic languages, involving statistically reliable material and a complex method, providing for a perceptual, acoustic (with reference to analysis) as well as mathematical and statistical types of analysis. It should be noted that by the syllable structuring of speech utterances is meant a regulated set of quantitative and qualitative links between the aforesaid speech segments regarded in speech dynamics.

The research was carried out as a multiple-stage experiment, characterized by the use of a variety of procedures and methods of analysis. The experimental material as applied to German, English, Swedish, Danish, Norwegian and Dutch was compiled according to the principle of inter-language minimal pairs and was varied in relation to a specific task set on a particular stage of research. The range of varieties of the analyzed language units encompassed both the words pronounced in isolation as well as the same words pronounced as parts of an utterance or a text. To solve a number of problems on the material of English and German a special set of test utterances differing in relation to the syllabic length and phonemic composition were selected. Besides, the inter-language minimal pairs chosen for

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German, English, Danish and Swedish allowed to analyze different juncture processes, Danish ejection (stød), Swedish accents I and II. In a number of cases material based on evidence from Russian was also used in the research. The total number of words, phrases, utterances and texts under consideration amounted to 1600 units.

The main hypothesis of the present study was formulated in the following way: segmental structuring of speech has a certain stratification and is characterized by a set of stable phonetic features, which can be described both in terms of acoustics and perception.

In accordance with the main hypothesis the *principle* objective of the present research was formulated. It consisted in the search for perceptual and acoustic correlates of the phonetic features enabling to describe segmental structuring of speech. A number of more *specific objectives* of the research resulted from the nature of the object under investigation at some stages of the experiment. The objective in question incorporated the search for a key perceptual quantum, categorization in the context of the syllable perception, determination of a perceptual and acoustic localization of the nucleus of the syllable carrier, revealing the nature of qualitative dynamics within the scope of a syllable carrier. search for acoustic correlates of syllabic parataxis in the Germanic languages, revealing the character of temporal correlation between different speech segments, identifying quantitative and qualitative markedness of the syllable within the framework of the utterance, search for acoustic correlates of some types of boundary signals in Germanic languages, detecting formal parametric features of speech segmentation, building a system of dynamic-melodic models as applied to Germanic languages under consideration, normalization of the findings.

Theoretical and practical implications of the present study and its results essentially boil down to a new trend in the field of descriptive typology of syllable structuring of speech. The obtained data are conducive to furthering and deepening the know-how in an independent branch of phonetic sciences - *syllable phonetics*, which has its own object to be investigated, specific methodology, a set of characteristic features, and practical applications. The findings were used for writing a number of manuals and implemented in practical teaching of phonetics.

Linear character of speech continuum presupposes realization of syllables varying in dimensions and organized in time. Such realization of syllables is impossible without the coexistence of phenomena of continuity and discreteness. Specific nature of passing from a continuous character of articulation to a discrete one depends on universal physiological factors, the basis of articulation of the language, its phonological peculiarities, concrete conditions of speech production. In this connection speech, as any other system, is a complex whole, and its constituent parts interact according to the principle of *multi-level stratification.*

The description of any system presupposes the choice of a reference object, which makes it possible to describe the system correctly. As applied to the present study, the syllable is considered as a reference object, while positional and contextual as well as qualitative and positional characteristics, segmental duration (length), temporal determinants etc. are regarded as factors, which influence syllable and syllabic constituents modifications. The problem of revealing the specific acoustic, articulatory and perceptual nature of the syllable, its phonological features was reflected in a number of studies and methods on the material of different languages. However, the aim of these research was the solution of the problem of

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temporal, dynamic and melodic nature of syllable with special reference to a particular language.

Functioning of the syllabic segment in the flow of speech makes it possible to differentiate between *rhythmic structures*, to grade accentuation in a given message and at the same time to integrate the components of the message into wholesale semantic structure. The principle of syllable quantization of speech promotes the proper realization and perception of an utterance. A correctly realized syllable sequence with allowance made for the rules of suprasegmental character leads to an adequate transmission of information in the process of communication. In the context of the aforesaid the syllable may be regarded as a many-faceted phenomenon due to the polyfunctional character of the latter (constitutive, culminative, delimitative, recognitive). From our point of view the phenomenon, which is traditionally called «a syllable», may be defined as a relatively stable segment of the flow of speech (from the standpoint of horizontal determinants), formed under the influence of the basis of articulation of the language and located at *the intersection of the semantic and asemantic scales*. The syllable may be described in terms of articulation, perception and acoustics, with the three types of description revealing its non-single-valued nature. The description of the phonetic features of syllable on the material of a number of languages makes it possible to reveal the degree of stability and mobility of separate components of the utterance, as well as of the degree of proximity or remoteness of the specific nature of the segmentation of the speech flow.

1.3. The methodology of research

The present experimental phonetic research was performed at the Laboratory of Experimental Phonetics of Moscow Linguistic University. Some experiments were carried out at the Laboratory of Experimental Phonetics at the Institute of the Russian Language of the Academy of Sciences, as well as in the Computer Center of the Academy of Sciences of Russia. In the course of study native informants acted as test subjects (speakers and listeners). The number of subjects varied, averaging to 25, and in some cases exceeding it. Every fragment of the experimental corpus was read in a studio with the terminal intonation in a full type pronunciation mode. Each utterance was read five times on different days. Perceptual analysis was first performed once and then repeated at certain intervals of time with a view to checking the data for the degree of scattering.

Original texts on the material of the languages under study were used as test samples. The available realizations were subjected to further acoustic and instrumental analysis. The analysis of F_0, I and t was performed with the help of computer programme CSL (Potapova, 1986).

1.4. The dynamic and melodic models (DMM) of syllable structures for Germanic languages

It is known that the most difficult task in teaching foreign pronunciation and in solving problems of automatical speech recognition is the task of correct syllabic encoding and decoding of an utterance. As the explication of the syllabic shape of an utterance - which serves the aims of optional speech communication as a whole - plays the leading role, we find

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it advisable to work out and describe dynamic and melodic models of different syllabic structures applied to all analyzed languages. In building up syllabic dynamic and melodic models by the method of graphic drawing such factors as phonetic quality and phonological and phonetic duration of a stressed vowel, consonant distribution, the type of the rhythmic pattern were taken into consideration. All dynamic and melodic models (DMM) of a syllable (36 - for German, 29 - for English, 19 - for Swedish, 28 - for Danish, 36 - for Norwegian, 18 - for Dutch) were obtained as a result of the statistic processing of a large amount of data (24.026 realizations) and represent the most stable generalized type of dynamic and melodic changes spread out in time with due regard to the above-mentioned linguistic factors. The obtained DMM allow us to fix the moments, which are the most important ones from the point of view of correct syllabic coarticulation; the number of intensity peaks in a vowel (one-peak, two-peaks, etc.); the rate of increase and/ or decrease in realization to the level of transitional sections; the development of a melodic curve in the whole structure and its constituents. The above-enumerated features enable us to single out some peculiarities of DMM of each analyzed language (Potapova, 1986).

For *German* DMM with a short vowel one peak of intensity is typical, the peak being located closer to the end of a vowel for central and back short vowels; but front short vowels are characterized by the shift of the peak to the beginning or to the center of a vowel. In German DMM with a long vowel there are two peaks of intensity, as a rule. The contour of the peaks depends on the quality of long vowels. Front long vowels are characterized by the increase of peaks level towards the end of the vowel, and the reverse configuration is typical of back vowels.

In *English* DMM with a short syllable-carrier one peak is fixed, which irrespective of the vowel quality is located, as a rule in the beginning or in the middle of vowel. Long vowels are characterized by a two-peak configuration, long close vowels being characterized by the decrease of intensity and long open ones - by the increase. It should be noted, that in both German and English DMM the number of peaks can exceed the described cases, the reason being the existence of independent peaks of intensity of segments, corresponding to sonorants and voiceless fricatives.

For *Swedish* DMM quite a different picture is typical. Short vowels are characterized by a two-peak configuration, long ones - by two- and three-peak configuration. Short vowels irrespective of their tongue positions have the similar configuration of peaks, which is characterized by an increase towards the end of the vowel. Long vowels are characterized by a gradual decrease of the intensity level, but also to auxiliary delimitative means. The differentiation of the Swedish accents I and II can also be related to additional means of segmentation in the Swedish language. The variety of interpretations of the prosodic nature of accents I and II does not essentially settle the problem. The research shows that in the realization of accents I and II dynamic and melodic transformation within the boundaries of a word as a whole takes place. Not separate sections and prosodic parameters of these sections, but *the correlation of these parameters* is important. So, for instance, the correlation of the stressed vowel duration in corresponding minimal pairs averages 1,2 : 1; the correlation of the duration of an intervocalic consonant (consonance) in the realization of the accent II in comparison with the accent I amounts to 1,3 : 1; the range of the intensity level for words with accent II is wilder and reaches 8 dB, while it reaches only 4 dB for corresponding words with accent I is 3 dB; the rise in the intensity level for the second vowel in the realization of accent

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II is 4 dB. In the realization of accent II F_0 forms a specific contour shaped as "two humps" and that confirms the view as to the presence of two "waves" in the realization of accent II. The research shows that in order to differentiate the Swedish accents I and II it is necessary to consider the type of the syllabic abutting which indicates the redistribution of syllabic boundaries in the analyzed structures. The strong initial realization of intervocalic consonants is typical, as a rule, of accent I; and the weak initial one - of accent II.

The Danish DMM are characterized by one-peak configurations (applied to a short syllable-carrier) and two-peak configurations (applied to a long syllable-carrier). In the latter case the contour of the fall dominates. If stød takes place, the intensity peak shifts to the end of the sound as much as possible. One of the most typical peculiarities of the Danish phonetic system is the presence of ejection (stød). It is known that ejection (stød) not only gives some specific coloring to the Danish language but in some cases it is capable of differentiating the meaning, and, as a result, is regarded as a specific glottal phoneme. The semantic distinctive character of ejection, as well as its distributional selectivity (stød as a rule is viewed as a constituent of the final position) give grounds to relate it to the peculiarities of the Danish phonotactics. The reason for stød - formation is usually connected with the break in phonation. The results of our research, which was conducted with the help of glotto-graphic technique on the material of minimal pairs, where the stressed vowels were followed by a stød and realized without the latter, enable us to conclude the following: with the presence of ejection the vibrations of the vocal cords are continuous throughout the duration of the vowel segment; at the stød section of an utterance a regular reduction in the vibration amplitude on observed; change in the vocal cords working mode at the moment of stød realization; the stød duration reaches half of the vowel duration. Therefore, a full stop of phonation does not occur in the moment of stød realization. However according to auditory analysis data one can assume that the short duration of this process and the presence of the vocalized phonetic context create the perceptive illusion of a full stop on phonation. The observation of speech dynamics shows that nowadays stød can be realized as a constituent not only of the final phase, but of the medial phase, too. The constant interaction between qualitative features applied to the medial and the final phases is shown, for instance, on the material of the Icelandic syllable, where the differences in duration and timbre are regulated by either the middle or the final positions.

In this relation the Danish syllable has obviously been influenced by the common Germanic tendency to distribute the features within the boundaries of the medial and final positions, that results among other things in the variabilities of the stød location in speech dynamics. The above mentioned data give us grounds to relate the stød not only to semantically distinctive but also to auxiliary delimitative means.

The typical feature of the Norwegian DMM is a considerable intensity level and duration of intervocal consonants. Short vowels have always one-peak configuration, long ones - two-peak falling configuration. The reciprocal location of the peaks does not depend on the vowel quality. It should be stressed that DMM of Norwegian syllabic structures have much in common with DMM of the Swedish language. DMM in the Dutch language have some peculiarities. Short vowels have the initial location of the peaks, but in comparison with German and English DMM, the transition to the following consonant does not occur on the near proximity to the peak, so it does not create the effect of a checked vowel, typical of German and English syllables. Semi-long vowels are characterized by two peaks, however the

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configuration of the peaks differs much from all the other cases described above. The intensity peaks in Dutch DMM are contrasted with, for example, German DMM, German long vowels have the same two-peak configuration which are located on almost the same level, and the following transitional section is located in the near proximity to the second peak as if «cutting it off» abruptly. The obtained DMM enable us to get the prosodic picture of German syllabic structures, which is of great importance in applying DMM to simulation pronunciation learning systems of different types based on visual control to be used for teaching purposes.

2. DYNAMIC AND MELODIC SYLLABLE MODELS FOR SLAVIC LANGUAGES

2.1. The DMM for Czech spoken language

The aim of this research was to determine by means of instrumental analysis the presence or absence of some objective regularities in changes of duration (t), fundamental frequency (F_0) and intensity (I) within the RS (rhythmic structure[1]) and RPS (rhythmic pattern of syntagma[2]) of the languages under consideration using material with different types of texts. The following prosodic parameters were used as supporting during the analysis: a) for duration – the main duration of RS in absolute values (ms), relative normalized main duration of RS within syntagmata, absolute and relative duration of vowels in RS, average vocalic duration in syntagma; b) for intensity - main relative intensity of vowels and sonorants in RS, maximal values of relative intensity of vowels and sonorants in RS; c) for fundamental frequency - values, averaged during the realization of every vowel (and/ or sonorant) within RS. It is known, that the speech prosodic features (fundamental frequency, duration and intensity) form an indivisible unity, in which it is possible to differentiate between the individual constituent elements only artificially for the purposes of scientific analysis.

All types of texts have been analysed as part of this study. We have revealed the following average data on the basis of Czech texts, containing description of documentation on technique with reference to the prosodic structure of RS:

1) for disyllabic RS:

a) the duration increase of a second vowel (e.g., $\bar{t}_{v1}$= 30 ms, $\bar{t}_{v2}$= 50 ms);

b) the equal or nearly equal fundamental frequency (e.g. $\bar{F}_{0v1}$= 230 Hz, $\bar{F}_{0v2}$= 220 Hz).

2) for trisyllabic RS with the stress on first syllable the prosodic variability is conditioned by the presence or absence of a phonologically long vowel in RS:

a) in RS without a long vowel the duration of vowels are equal (e.g. $\bar{t}_{v1}$= 40 ms, $\bar{t}_{v2}$= 40 ms, $\bar{t}_{v3}$= 40 ms);

b) in RS with a long vowel in the middle position the maximal value of duration is connected with a second vowel (e.g. $\bar{t}_{v1}$=40ms, $\bar{t}_{v2}$=80ms, $\bar{t}_{v3}$=40ms);

c) in RS with a long vowel in the final position the duration reaches its maximal peak value by realization of a third vowel (e.g. $\bar{t}_{v1}$= 40ms, $\bar{t}_{v2}$=40ms, $\bar{t}_{v3}$= 80ms);

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[1] Rhythmic structure, or RS, is understood as one or several syllables of words (both significative and auxiliary) united by a single primary word stress (Potapov, 1991).

[2] Syntagma is understood as a phonetic and syntactic unity expressing single notion in the process of speech-thinking. It is a higher linguistic unit than RS.

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d) in all cases (with a long vowel in RS and without it) maximal intensity value becomes localized on a second vowel in the center of RS(e.g. $\bar{I}_{max\ v1}$=45, $\bar{I}_{max\ v2}$=58, $\bar{I}_{max\ v3}$=43);
e) the fundamental frequency values either don't change (e.g. $\bar{F}_{0v1}$= 240Hz, $\bar{F}_{0v2}$= 240Hz, $\bar{F}_{0v3}$= 240Hz), or remain similar (e.g. $\bar{F}_{0v1}$=200Hz, $\bar{F}_{0v2}$=210Hz, $\bar{F}_{0v3}$=220Hz).
3) for tetrasyllabic RS the prosodic variability is not very large. Even the presence of long vowels does not influence the analyzed parameters values greatly:
a) the least duration value characterizes a first vowel in RS, gradual duration increase is observed for the subsequent vowels (the second and the third). The long vowels according to duration are distinguished particularly. To the end of RS the duration once again falls, reaching its original value or approaching to it (e.g. $\bar{t}_{v1}$=40ms, $\bar{t}_{v2}$=60ms, $\bar{t}_{v3}$=70ms, $\bar{t}_{v4}$=80ms). In tetrasyllabic RS least duration is in the final and the initial parts of the structure. At the same time the duration increasing in the centre of RS can be regarded as time compensation. Exceptions to the rule are tetrasyllabic RS with a long vowel (e.g. $\bar{t}_{v1}$=50ms, $\bar{t}_{v2}$=40ms, $\bar{t}_{v3}$=60ms, $\bar{t}_{v4}$=60ms);
b) change of intensity may be of two kinds: the increase and fall to the end of RS (e.g. $\bar{I}_{max\ v1}$=45, $\bar{I}_{max\ v2}$=45, $\bar{I}_{max\ v3}$=50, $\bar{I}_{max\ v4}$=53; $\bar{I}_{max\ v1}$=45, $\bar{I}_{max\ v2}$=42, $\bar{I}_{max\ v3}$=40, $\bar{I}_{max\ v4}$=40). The existence of variants is connected with the position of tetrasyllabic RS in syntagma. In the first case RS is realized in all positions, excepting the final one, in the second case only in the final position;
c) change of fundamental frequency values in tetrasyllabic RS is characterized by two variabilities, which as well as intensity depends directly on RS position within a syntagma: the final position fundamental frequency either increases (e.g. $\bar{F}_{0v1}$=180Hz, $\bar{F}_{0v2}$=180Hz, $\bar{F}_{0v3}$=220Hz, $\bar{F}_{0v4}$=220Hz), or falls (e.g. $\bar{F}_{0v1}$=180Hz, $\bar{F}_{0v2}$=180Hz, $\bar{F}_{0v3}$=160Hz, $\bar{F}_{0v4}$=160Hz). In the middle position the fundamental frequency values have equal or very similar characteristics (e.g. $\bar{F}_{0v1}$=210Hz, $\bar{F}_{0v2}$=200Hz, $\bar{F}_{0v3}$=200Hz, $\bar{F}_{0v4}$=210Hz).
4) For pentasyllabic RS a certain values variability of duration and intensity is also observed:
a) as far as duration is concerned two main variants exist: the duration increase on the second vowel and on the final (on penultimate vowel and last one, which forms as it were timing peaks and the duration increase in phonological long vowels out of influence from its position with one timing peak (e.g. $\bar{t}_{v1}$=60ms, $\bar{t}_{v2}$=100ms, $\bar{t}_{v3}$=70ms, $\bar{t}_{v4}$=60ms, $\bar{t}_{v5}$=80ms; $\bar{t}_{v1}$=50ms, $\bar{t}_{v2}$=60ms, $\bar{t}_{v3}$=40ms, $\bar{t}_{v4}$=60ms, $\bar{t}_{v5}$=40ms);
b) vowel intensity of RS varies slightly. But mostly the second and the third vowels in RS are marked by intensity, i.e. its centre (e.g. $\bar{I}_{max\ v1}$=40, $\bar{I}_{max\ v2}$=45, $\bar{I}_{max\ v3}$=40, $\bar{I}_{max\ v4}$=20, $\bar{I}_{max\ v5}$=20);
c) the fundamental frequency curve depends entirely on RS position in syntagma, and it is characterized by even contour in the middle, rising at the beginning of syntagma and the end of a non-terminal syntagma, falling - at the end of a terminal syntagma.

In essence similar tendencies of duration, intensity and fundamental frequency distribution are inherent in sextasyllabic RS. The comparison of duration values in RS irrespective of its syllable length showed, that the vowel duration in RS increases in the following cases: in the phonologically long vowels and also in a wide vowel, that is not long. Subsequent specificity of duration in RS distribution is conditioned by the number of syllables in RS. The vowels in RS are marked by intensity only in the initial part of a syntagma, which is conditioned by universal physiological factor. The same analysis has been carried out on the basis of texts, belonging to the genre of instruction on technique and newspaper.

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The phonetic specificity of Czech rhythm, viewed as a unity of different manifestations of fonation and articulation, is conditioned by absence of reduction, by approximately equal, very insignificant duration realization of reduced vowels; approximately equal intensity of vowels of RS and high intensity and duration for all sonorants, presence of glottal stop in uncovered initial position of RS (moreover this phenomenon is typical for vowels forming the sound envelope not only of categorematic, but also of syncategorematic parts of speech); by marked intensity and duration of initial vowels in RS at the beginning of a phrase and/ or syntagma, by a small degree of melodic brokenness, which is transmitted by an either monotonously decreasing or monotonously increasing melodic curve.

On the whole, all forementioned prosodic features of RS in Czech speech makes it possible to speak about specificity of Czech rhythm, which consists in equal markedness of vowel realization (with the exception of vowels with phonological length), in the existence of glottal stop of initial uncovered vowels, special markedness of consonants (sonorants, vibrants, etc.), even melody and dynamics.

It was necessary to analyse the prosodic organization or RS within larger segments after research of distribution of prosodic features within the limits of each RS, i.e. syntagmata and phrases. Here all the material was also analysed first of all separately in texts of different genres and then the obtained data were compared and their distinguishing features were determined. The examination of the prosodic RS features in syntagmata and phrases makes it possible to correlate the prosodic features of each RS with the general syntagma and phrase structure as it were in the dynamics of speech production. As a result of the studying the following prosodic parameters have been registered: relative (normalized) RS duration of syntagma (in %), relative duration of RS vowels syntagma, main relative intensity of vowels and its averaged intensity in RS, fundamental frequency changes. The relative duration of each RS was examined in connection with the total duration of the whole syntagma, and relative duration of vowels in RS - in connection with the average duration of vowels in a syntagma, i.e. average duration value of vowels within a syntagma serves as normalization unit.

The total value of intensity of RS is distributed also depending on the position of RS within a syntagma: there are values at the second place from the beginning of syntagma and the least ones - at the end (e.g. Σ_{I1RS}=273, Σ_{I2RS}=286, Σ_{I3RS}=197, Σ_{I4RS}=225). There are cases, when the maximal total intensity characterizes the first RS within a syntagma (e.g. Σ_{I1RS}=107, Σ_{I2RS}=84, Σ_{I1RS}=109, Σ_{I2RS}=87, Σ_{I3RS}=56). Average intensity values of RS in syntagma are approximately equal (e.g. $\overline{I}_{1RS}$=48, $\overline{I}_{2RS}$=46, $\overline{I}_{3RS}$=48, $\overline{I}_{4RS}$=33). The exception, as a rule, is average intensity of RS in the final position. The fundamental frequency changes as a whole fall up to 0–2 semitones. It is particularly evident in the middle segment of a syntagma.

Isochronism of absolute and relative values of duration of stressed and unstressed syllables is observed in syntagmata in texts of Czech fiction prose too. Stressed syllables are shorter than final ones in RS, which is typical for all "wide" and "narrow" vowels.

Thus, the results of the analysis of prosodic features within the rhythmic frames of syntagmata for Czech speech are the following: equal power markedness of syllables is observed, as a rule, for realization of syntagma of texts of prose (both non-fiction and fiction). For fundamental frequency data there is a tendency to functioning of monotonous contours. The

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research of duration in each RS within a syntagma and their comparison the basis of acoustic parameters showed, that isochronous RS are observed within a syntagma. Moreover, the stressed vowels are isochronous. But at the same time it is very important to point out that all parameters of duration, fundamental frequency and intensity have closer values in non-fiction texts, than in texts of fiction prose.

2.2. The DMM for Bulgarian spoken language

At the next stage of research the prosodic features of RS and RPS were analysed in Bulgarian texts, containing description, instructions and documentation on the domain of technique, newspaper articles etc. The same prosodic parameters were used as the basis for analysis as in the analysis of Czech speech, i.e. absolute main duration of RS in syntagma, relative main duration of RS in syntagma, absolute vowel duration in RS, relative maximum intensity on each vowel within RS, total intensity of vowels in RS, average intensity of vowels in RS, fundamental frequency changes in Hz and semitones, treated with an orientation on average values of fundamental frequency of each vowel in RS and interval between them.

Some examples of distribution of the prosodic features can be given with regard to syllable length of RS and place of stress.
1) for disyllabic RS:
a) the duration increase on the stressed vowel is characteristic feature (e.g. $\bar{t}_{v1}$=90ms, $\bar{t}_{v2}$=60ms);
b) the same feature is characteristic of the maximum intensity value of stressed vowels (e.g. $\bar{I}_{v1}$=16, $\bar{I}_{v2}$= 13);
c) the change of fundamental frequency is observed regularly on the speech segment from stressed vowel to next vowel after the stressed one (e.g. $\bar{F}_{0v1}$=180Hz, $\bar{F}_{0v2}$=170Hz; $\bar{F}_{0v1}$=210Hz, $\bar{F}_{0v2}$=230Hz). Moreover, it may be variability of the direction of such change.
2) for trisyllabic RS:
a) maximum duration on the stressed vowel is characteristic feature (e.g. $\bar{t}_{v1}$=60ms, $\bar{t}_{v2}$=100ms, $\bar{t}_{v3}$=80ms);
b) the same parameters are observed for distribution of values of intensity in RS (e.g. $\bar{I}_{v1}$=15, $\bar{I}_{v2}$=25, $\bar{I}_{v3}$=23);
c) the change of fundamental frequency accompanies the appearance of stressed vowels in RS (e.g. $\bar{F}_{0v1}$=220Hz, $\bar{F}_{0v2}$=220Hz, $\bar{F}_{0v3}$=250Hz).
3) for tetra-, penta, sextasyllabic RS:
a) stressed vowels are characterized by maximum duration (e.g. t_{v1}= 40 ms, t_{v2}= 40 ms, t_{v3}= 20 ms, t_{v4}= 60 ms, t_{v5}= 40 ms, t_{v6}= 40 ms). Moreover, this quantitative markedness is observed in all stressed wide monophthongs (without exception) as well as narrow ones (e.g. $\bar{t}_{\text{â}}$=60ms, $\bar{t}_{\text{û}}$=70ms, $\bar{t}_{\text{é}}$=60ms), and also diphthongs (e.g. $\bar{t}_{\text{îé}}$=100ms);
b) the same parameters characterize intensity of stressed vowels (e.g. $\bar{I}_{v1}$=17, $\bar{I}_{v2}$=17, $\bar{I}_{v3}$=15, $\bar{I}_{v4}$=32, $\bar{I}_{v5}$=28, $\bar{I}_{v6}$=25);
c) the values of fundamental frequency as in all previous cases are characterized by the presence of great advance (leap forward, sudden change) from average value of fundamental frequency of the preceding vowel to average value of fundamental frequency of the subsequent vowel according to the following scheme: "a pretonic vowel - a stressed vowel"

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and "a stressed vowel - a vowel after the stressed one" (e.g. $\bar{F}_{0v1}$=160Hz, $\bar{F}_{0v2}$=170Hz, $\bar{F}_{0v3}$=170Hz, $\bar{F}_{0v4}$=200Hz, $\bar{F}_{0v5}$=170Hz, $\bar{F}_{0v6}$=160Hz).

Thus, phenomena of two kinds are revealed in the Bulgarian language on the basis of spoken texts for RS: a general phenomenon for different types of texts and variability, which is typical for this or that type of texts. In the first case one can speak of stable character of acoustic markedness of stressed vowel by all prosodic means and, first of all, by duration and intensity, secondly - difference in structural relation between these means. Larger dynamic range in stressed vowels of RS and larger contrast of duration between unstressed and stressed vowels in RS, as it was mentioned above, is a result of larger expression in spoken realization of newspaper texts in comparison with less degree of expression in spoken realization of texts of technical documentation. A wider range is another manifestation of it. Compare: from 1 semitone up to 10 semitones in social and political texts (from newspaper) and from 1 semitone up to 5 semitones in texts (documentation on technique).

The syntagmatic (or phrase) stress within RS can influence total duration of RS in the Bulgarian speech. In such cases the total duration of RS exceeds regularly average duration of RS in syntagma (or phrase).

A regular shift of total and average intensity values of RS in the construction of a syntagma (phrase) was determined in the direction from the beginning of a syntagma (phrase) to its end - a zone of smaller values (e.g. $\sum_{I1RS}$=349, $\sum_{I2RS}$=135, $\sum_{I3RS}$=99). We can interpret similar shift from the general physiological aspect of speech production.

Regular changes of prosodic features are not observed the on boundaries of RS: values of fundamental frequency vary but they manifest themselves more often in the absence of melodic interval; values of intensity in the last vowel of RS and in the first vowel of subsequent RS also vary in their values, as well as in their change.

The syllable ratio in RS according to intensity is characterized by the fact that maximum value of intensity, as a rule, have localization on stressed syllable, smaller values - on adjacent syllable (pretonic vowel) and the syllable after stressed one in the position of contact. The general descriptive scheme of intensity distribution in Bulgarian RS, if we take number 2 as maximum value of intensity, 1 - middle, 0 - minimum, is of the following type: a) RS 2/1[3] - 2-1; b) RS 2/2 - 1-2; c) RS 3/1 - 2-1-1; d) RS 3/2 - 1-2-1; e) RS 3/3 - /0/1-1-2/1/; f) RS 4/2 - 1-2-1/0/-0/1/; g) RS 4/3 - 0/1/-1/0/-2-0/1/; h) RS 4/4 - 1-0-0-2; I) RS 5/2 -1-2-1-0-0; j) RS 5/3 - 0-1-2-1-0/1/; k) RS 6/4 - 0-0-0/1/-2-0/1/-0/1/; l) RS 7/6 -0-1-1/2/-1-0-2-1.
Some deviations from the rule in distribution are possible due to realization of wide and narrow vowels in RS. In such cases maximum intensity is derived from wide unstressed vowels, and narrow stressed ones are characterized by smaller values of intensity. For example, for RS 2/1 ([ú] - [a]) formula has the following type: 1-2; for RS 5/3 - ([u] - [ъ] - [é] - [u] - [e]) - 1-2-1-0-0.

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

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The comparison of the total duration of each RS within a syntagma has revealed the absence of isochronism in Bulgarian, which is a striking contrast to Czech. A greater degree of melodic variability and a wider intonation range of Bulgarian as compared to Czech can also be mentioned among linguistic peculiarities. Stress patterns are also different in the two languages: in Bulgarian the RS stress is maximum in value and coincides with the lexical stress (the syllable with the primary stress) while in Czech it is observed in the transition segment from the final vowel of one RS to the initial vowel of the subsequent RS. Czech speech flow is characterized by a prosodic markedness of the beginning and of the end of RS. In Bulgarian regular prosodic features of this type are not observed.

2.3. The DMM for Russian spoken language

The same analysis has been carried out on the basis of texts in Russian (documentation and instructions on technique and newspaper articles). The same set of parameters has been analysed as in Czech and Bulgarian.
The following parameters are observed:
1) for disyllabic RS:
a) the absence of any regular trend in distribution of maximum values of duration and intensity on the stressed vowel (e.g. $\bar{t}_{\acute{v}1}$=130ms, $\bar{t}_{v2}$=60ms; $\bar{t}_{v1}$=100ms, $\bar{t}_{\acute{v}2}$=100ms; $\bar{t}_{v1}$=80ms, $\bar{t}_{\acute{v}2}$=140ms; and $\bar{I}_{\acute{v}1}$=47, $\bar{I}_{v2}$=60; $\bar{I}_{v1}$=22, $\bar{I}_{\acute{v}2}$=15);
b) the regular markedness of stressed vowels by fundamental frequency interval (e.g. $\bar{F}_{0\acute{v}1}$=200Hz, $\bar{F}_{0v2}$=250Hz; $\bar{F}_{0v1}$=250Hz, $\bar{F}_{0\acute{v}2}$=170Hz);
2) for trisyllabic RS:
a) a frequency occurring discrepancy between maximum values of intensity and duration with stressed vowel (e.g. $\bar{t}_{v1}$=60ms, $\bar{t}_{\acute{v}2}$=90ms, $\bar{t}_{v3}$=110ms; $\bar{I}_{v1}$=64, $\bar{I}_{\acute{v}2}$=53, $\bar{I}_{v3}$=25);
b) regular interval of the fundamental frequency on a segment from an unstressed vowel to a stressed one and from a stressed vowel to the subsequent vowel (after stressed one) (e.g. $\bar{F}_{0v1}$=320Hz, $\bar{F}_{0\acute{v}2}$=200Hz, $\bar{F}_{0v3}$=150Hz);
3) for tetrasyllabic RS:
a) the absence of markedness of maximum values of duration and intensity on stressed vowels (e.g. $\bar{t}_{v1}$=40ms, $\bar{t}_{v2}$=60ms, $\bar{t}_{\acute{v}3}$=60ms, $\bar{t}_{v4}$=40ms; and $\bar{I}_{v1}$=22, $\bar{I}_{\acute{v}2}$=17, $\bar{I}_{v3}$=13, $\bar{I}_{v4}$=18);
b) changes of fundamental frequency are characterized by the same tendency ($\bar{F}_{0v1}$=330Hz, $\bar{F}_{0v2}$=380Hz, $\bar{F}_{0\acute{v}3}$=300Hz, $\bar{F}_{0v4}$=320Hz). The same distribution of forementioned parameters is observed in polysyllabic RS, whose length exceeds four syllables.

The existence of maximum values of duration and intensity in RS has at the same time internal order: a stressed vowel is marked, as a rule, either by duration and then intensity increases on the preceding and/ or initial syllable of RS, or by intensity and then duration increases mostly on a final syllable of RS, for example, in RS 6/4: $\bar{t}_{v1}$=40ms, $\bar{t}_{v2}$=40, $\bar{t}_{v3}$=40ms, $\bar{t}_{\acute{v}4}$=110ms, $\bar{t}_{v5}$=90ms; $\bar{I}_{v1}$=38, $\bar{I}_{v2}$=40, $\bar{I}_{\acute{v}3}$=70, $\bar{I}_{v4}$=55, $\bar{I}_{v5}$=50. Using designations «2 – maximum parameter value, 1 – middle, 0 – minimum», this ratio may be formalized as:
4) for RS 5/4:
a) according to duration: 0 0 0 2 1;
b) according to intensity: 0 0 2 1 1;
c) in total: 0 0 **0** **2** 1
0 0 **2** **1** 1

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5) for RS 2/1:
   a) according to duration: 2 0;
   b) according to intensity: 1 2;
   c) in total: **2** 0;
6) for RS 4/3:
   a) according to duration: 0 1 2 0;
   b) according to intensity: 0 2 1 0;
   c) in total: 0 **1 2** 0
   0 **2 1** 0

Therefore, the stressed syllables in RS exist according to the principle of compensation of the prosodic parameters in Russian texts: either dynamically or quantitatively with additional melodic component. The general modification of parameters is related to a segment of more than one vowel. Obviously, for stress in RS not only prosodic but also spectral (qualitative) features are relevant for Russian speech.

The factor of syllable length of RS in syntagma has a greater influence on RS duration, than RS's position within a syntagma (phrase). But despite this fact we can detect slight increase of RS duration in the direction from the beginning of a syntagma (phrase) to its end. Nevertheless, this duration of RS within a larger speech structure is not always observed.

Another pattern is a characteristic feature of RS *intensity*. The total intensity of every RS within a syntagma (phrase) and also its average intensity is characterized by decrease of values from the beginning of a syntagma (phrase) to its end (e.g. Σ_{I1RS}=190, Σ_{I2RS}=171, Σ_{I3RS}=96). This type of distribution, as other scholars noted, is universal. Thus, RS at the beginning and the end of a syntagma (phrase), as a rule, are marked: the beginning - by maximum total and average intensity and minimum total duration, and the end – by minimum total and average intensity and by maximum total duration. No great differences were registered while comparing the prosodic features of texts of documentation on technique and newspaper articles.

The correlation between time of realization of vowels and general time of realization of RS is 43% in Russian texts, i.e. 43% of all spoken material is related to vowels. Consequently, consonantism in Russian speech is represented by a greater time duration, than vocalism, which can be explained by reduction.

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 per cent), average duration of vowel, 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 (Potapov, 1996).

In terms of total duration of vowels in the syntagma, the three languages are characterized by the following data:

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Table 1 Total duration of vowels in the syntagma in Bulgarian, Russian and Czech

Languages	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. Bulgarian is characterized by the smallest ration of the vowel to consonant duration.

Concerning average vowel duration, we can say that Russian has the highest values of this parameter ($\bar{t}_v$=80ms). Bulgarian and Czech do not differ in this respect ($\bar{t}_v$=60ms). 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 ($\bar{t}_s$=205ms) and the minimum one in Bulgarian ($\bar{t}_s$=137ms) while in Czech this parameter is intermediate in value ($\bar{t}_s$=160ms). 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 figures being $\bar{t}_{\Sigma RS}$=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 syntagmata 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 syntagmata into RS (on the average 5 RS in a syntagma), a fast speech rate and reliance in

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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 syntagmata 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 an parameter having the greatest information content in terms of the speech flow segmentation into RS. Maximum intensity and the rate 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.

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.

2.4. Conclusion

The comparison of the results obtained on the basis of Germanic and Slavic languages made it possible to find the indicative parameters, such as duration, intensity and fundamental frequency for differentiation between rhythmic patterns of languages under consideration. The same results were obtained for dynamic and melodic syllable models and prosodic segmentation of these languages (Potapova, 1991; Potapova, 1993). The typical differences of DMM of RS for German and Russian are showed in figures 1–6.

The problem of prosodic syllable modeling of speech is very complicated, it includes various problems: linguistic, psychological, physiologic, etc. In the course of a forementioned experiment it was found out that the prosodic information plays an important role for segmentation of spoken texts of languages under consideration into syllables, syllable rhythmic structures, etc. In the future it would be perspective to find universal and specific DMM for many groups of languages.

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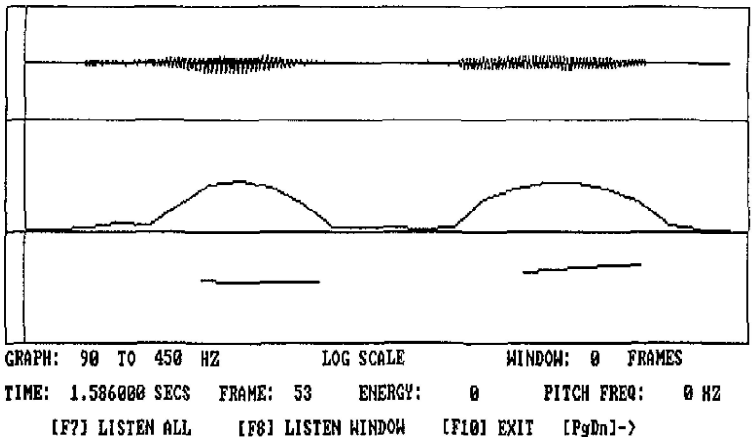

Fig. 1. The typical DMM of disyllabic RS 2/1 («Kasse») for German.

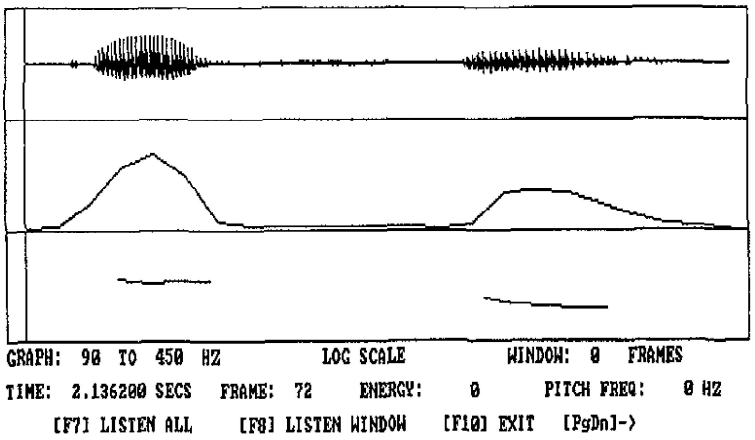

Fig. 2. The typical DMM of disyllabic RS 2/1 («Kasse») for Russian.

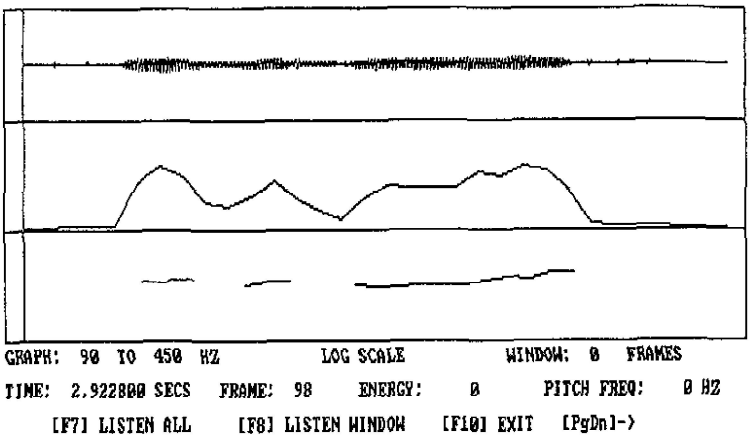

Fig. 3. The typical DMM of trisyllabic RS 3/3 («Präsident») for German.

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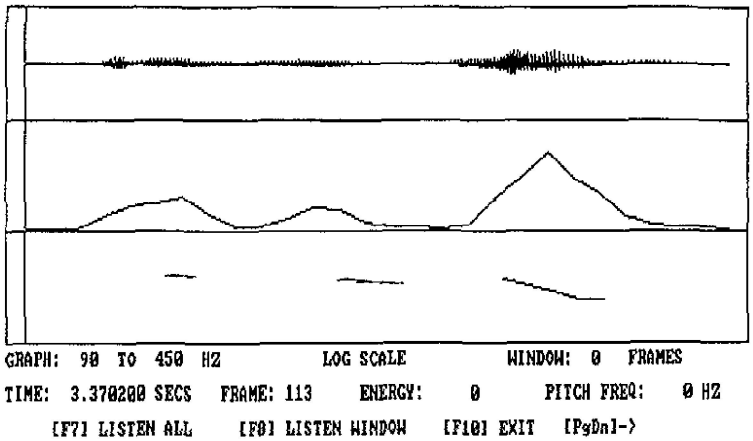

Fig. 4. The typical DMM of trisyllabic RS 3/3 («Präsident») for Russian.

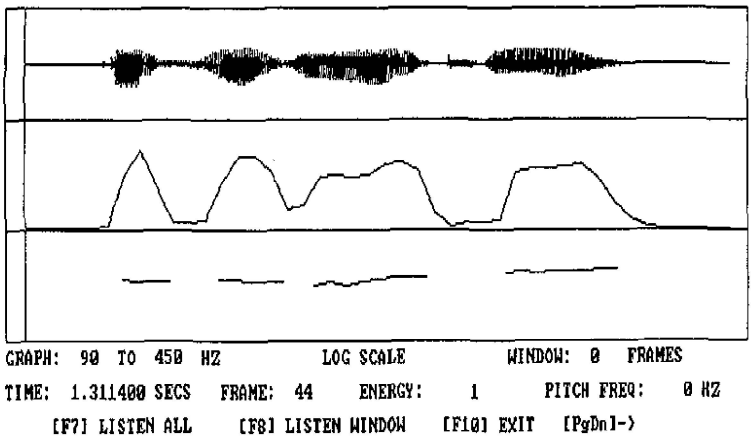

Fig. 5. The typical DMM of tetrasyllabic RS 4/3 («Apparate») for German.

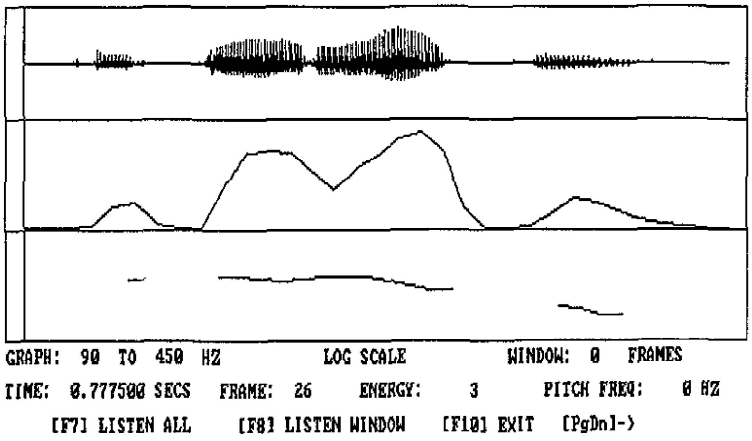

Fig. 6. The typical DMM of tetrasyllabic RS 4/3 («Apparate») for Russian.

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