

Rhythmic and tonal correlates of focus in Greek

Master dissertation

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2 Introduction

This thesis is dedicated to the study of prosodic phenomena with reference to focus structures in Greek. Focus is a complex phenomenon linking “significant” to “signifié” through prominence assignment on sentence level, giving thus a road map for decoding the wider context. Focus production in spoken language involves interactions between the following language components:

- phonetic component as it can be expressed by changes in accents' placement
- syntactic component as it can be expressed by changing the word order or introducing different syntactic construction
- semantic component as it plays an important role in building informational structure of the utterance.

Relation between those components can be described within the framework of a straightforward hierarchical model on top of which are the syntactic structures [Chomsky, 1995]. On the other hand, interaction between phonological and syntactic constituents can be investigated as phonological constraints influence syntactic structures and syntactic rules have impact on the phonological ones [Inkleas & Zec, 1995].

Describing a phenomenon of human language, it is important to keep in mind that one of its main characteristics is multi functionality. Although each language level (i.e. phonology, syntax, discourse) is usually separately investigated, we should not forget that during the communication process all language levels interact affecting certain parameters of each level's structure [Wardhaugh, 1992]. That is a good reason for trying to study language phenomena through a prism of multifactor analysis as there is a complex system of intercorrelations rather than one to one correlation. Here we shall introduce the structural complexity to analysis of focus production in spoken language.

Therefore the main goal of the present study is to make the first step in developing an integrated approach to examining focus, alternative to the conventional one traditionally used for analysis of focus.

Within the framework of integrated approach suggested here, focus should be described in terms of interaction between all tonal components and further on between tonal and syntactic correlates. In the present investigation

we will concentrate on the tonal aspect and the following questions will be addressed:

1. What is the impact of focus on rhythmic structure of simple utterances?
2. Does focus application have impact on stress group duration?
3. Does focus application have impact on utterance duration?
4. Is there any correlation between stress group duration and number of syllables it consists of?
5. What is the impact of focus on tonal structure?
6. Does focus application change tonal structure of the utterance?
7. Does focus have any impact on F0 peak rates?
8. Does focus have any impact on F0 lows rates?
9. What are the correlations between focus, duration and F0 movement?

According to the questions stated above in the present study fundamental tonal, rhythmic and focus structures in Greek three-constituent sentence production are being analyzed. For this reason tonal characteristics of the sentences representing four possible focus placements – None, Subject, Verbal Phrase and Object – were examined.

3 Theoretical background

In this section the notions of intonation, rhythm and focus are being examined as they were introduced within the framework of the previous studies as well as the main terms as a part of different approaches to investigating them. Observing the evolution of perceiving the role of focus in message encoding and decoding process we present the integrated view on focus as language phenomenon and not just a way of presenting information.

Intonation

Presenting the notion of intonation it would be hardly possible to review all the past studies on prosody or intonation as such a historical description falls out of the scope of the present study. What is considered necessary here is to introduce the basic concepts of the current intonation theories in order to support the idea of a complex multifactor analysis of prosodic phenomena.

There are two major approaches to studying intonation:

Morphological approach with focus on functional representations which encode the information necessary for syntactic and semantic interpretation of prosody (Brazil, Gussenhoven, Couper-Kuhlen, Kohler, Martin, Rossi). The key-notion for this approach is interpretability of a phenomenon both at concrete and at abstract levels.

Descriptive approach investigating the direct linkage between the acoustic substance and meaning. For this approach important is the concept of intonation contours such as sentence types etc. (Pirrehumbert, Beckman, Hirst, Di Cristo, Ladd, Mertens, Cruttenden, Fónagy, Kratochvil, Potapova, Svetozarova).

Thus, the first approach could be also named hierarchical as it studies intonation placing it in a strict hierarchy of language grammar; the second approach could be called also linear, as intonation contours are described as certain sequences of tones. Within the framework of the hierarchical approach suprasegmental level is being introduced as an independent level at which F₀ movements acquire their phonological meaning. Furthermore, it seems that all the models including the linear ones are in some way superpositional as they are treating accents as local elements forming intonation contour defined either empirically (Gårding, Grønnum), mathematically (Fujisaki) or psycholinguistically (t'Hart & Collier).

Intonation can be described in terms of tone – pitch differences perceived as variations of the fundamental frequency (F0), as absolute pitch values appear depending on non-linguistic factors such as sex, age etc. [Hartmann, 2007]. The rules assigning phonetic values to tones are the basis on which F0 contour is built connecting one tone to another. An important question in prosodic research is whether each tone contributes individually to the interpretation of an utterance or intonational meaning can be determined by a tune as an entirety. Here again comes the difference between hierarchical approach describing intonation as suprasegmental level in the linguistic hierarchy and the linear approach treating acoustic phenomena as they occur in sound sequence.

Apart from F0 level changes analyzing intonation is impossible without placing these changes in time investigating the duration component as well as matching those changes with sound, word, utterance boundaries. Thus, intonation consists of three phonological components:

- phrasal tones that are identified through the F0 movement
- metrical representation anchoring sounds to time
- lining up tunes connecting sound blocks

Describing phrasal tones it would be impossible to ignore the speaker's voice characteristics, intrinsic frequency and amplitude of the sounds, presence of boundary tone etc.

Any experimental study that involves durational aspect should deal with the following factors:

- The intrinsic timing of the gestures involved (e.g. the tongue-tip is a more agile articulator than the lips; it generally takes longer to open the vocal tract for a low vowel than for a high vowel, since more motion is required)
- Pre-boundary lengthening: a systematic *rallentando* at the ends of words and phrases
- Stress and emphasis
- Speaking rate (which can vary for many reasons)
- The real-time effects of composing and performing the message (e.g. slowing or pausing).

Describing intonation though is not just stating the facts based on simple measurements it is also unveiling regularities in the measurements linking the acoustic and semantic facts and building a model of speech production.

Rhythm

Since human language is a form of organized sound much similar to music, rhythm plays a significant role in forming tonal structure of the utterance as it deals with duration, segmentation and alignment. Rhythmic structure plays a very important role in organizing prosody of the utterance as prosody is formed by rhythm, stress and pitch.

A basic category used in describing rhythmic structure is “stress group”, alias “foot”, “prosodic word” etc., which is defined as a speech unit consisted of a stressed syllable and any unstressed syllables that may follow up to, but not including, the next stressed syllable [Pike 1946, Abercrombie 1967, Grønnum 1998]. The dominant role in sorting speech signal belongs to stress. The notion of stress refers to that what assigns prominence to a syllable forming phonetic word [Botinis, 1989, Bolinger, 1980, Vouper-Kuhlen, 1986, Warren, 1999]. Stress has a number of phonetic correlates such as: pitch, duration, loudness.

Summing up we can say that rhythmic sequences are created by interchanges of tension and relaxation, as more muscular effort is involved in production of prominent, stressed syllables [Bolinger, 1986, Abercrombie, 1967, Ladefoged, 1982, Schlueter, 2005]. In this aspect it can be said that rhythmic patterns are physiologically conditioned by inhalation-exhalation phases and muscles tension-relaxation [Lehiste, 1970, Bolinger, 1964]. Thus, in some extent rhythm facilitates language production.

Since rhythm, as stated above, is an intrinsic parameter of language, it is likely to carry some communicative functions. According to Allen rhythm is nothing more than auxiliary function that does not carry much information [Allen, 1975]. Many linguists agree that the main function of rhythm is segmenting speech into words, facilitating better perception of speech signal [Abercrombie, 1967, Lehiste, 1970].

Languages are typologically classified as “stress-timed” and “syllable-timed”, according to which stress groups and thus interstress intervals tend to be isochronous in stress-timed languages, such as English and Russian, whereas, in syllable-timed languages, such as French and Spanish, the interstress intervals are basically related to the number of syllables. Absolute isochrony has hardly been reported for any language and the main question is about relative isochrony, which may vary between different languages with different prosodic structures, as rhythm is deeply connected to syllable structure and intrinsic characteristics of the vowels of each language. Rhythm in language is closely related to duration parameter being expressed/perceived through manipulations of syllable durations and stress placement intervening in stress group durations. Such a close relation between rhythmic structure and duration can be expressed in defining rhythmic unit as a durational pattern which occupies a period of time.

Isochrony classification is performed according to the following criteria:

- Contrast in stressed/unstressed syllables' properties
- Lexical determination of stress placement in the words
- Compensatory lengthening of stressed syllables in stressed clashes [Nespor & Vogel, 1989, Selkirk, 1984]
- Compensatory shortening, vowel reduction and temporal compression of unstressed syllables [Nespor & Vogel, 1989, Selkirk, 1984]

In case language displays these characteristics to a high level it is considered stress-timed while in the opposite case it is considered to be syllable-timed. Considering the criteria by themselves it is obvious that any clear-cut differentiation is hardly possible on basis of production data. Empirical evidence on acoustic grounds and physical measurements is basically ambiguous, which has urged phonetic investigators to consider isochrony as a perception rather than a production process [Lehiste, 1977, Dauer, 1983, Ramus, Nespor & Mehler, 1999]. Such a conclusion is supported by the fact that there is a correlation between languages of different rhythmic types and strategies their speakers use to segment words and syllables [Cutler, 1997].

Fraisse in his study of psychology of rhythm fundamental correspondence between executed and perceived rhythms [Fraisse, 1974]. Although he does not come to a conclusion whether the ability to produce rhythms derives from the ability to perceive them or visa versa, he believes that rhythm production and perception are synchronized and thus highly related.

In conclusion to all mentioned above, we should say that rhythm involves more than one dimension and more than two categories, the fact that creates much confusion in studying it and building reliable rhythmic taxonomy [Lieberman, 2008]. In order to resolve it, scale approach to rhythmic taxonomy should be applied placing languages in the continuum of rhythm between the two poles rather than distributing them to two groups. As rhythm types belong to psychological rather than to physical dimension, rhythmic taxonomy should be attributed to phonological properties of each language [Dauer, 1987, Auer, 2001, Dufter, 2003].

Focus

Focus is considered a genuinely semantic-pragmatic notion that serves for communicating a set of ideas considered to be new for the listener. The basic linguistic function of focus is, thus, the semantic weighting of variable linguistic units in relation to information structure and contextual specifications of actual utterances. Various interpretations of focus-related intonational meanings have been made in terms of given-new information structure [Halliday, 1967, Chafe, 1976], in terms of topic and comment [Kuno, 1972], affected by the relations to presupposition-focus pairs [Chomsky, 1971, Jackendoff, 1972, Williams, 1980]. Previous studies of focus usually were conducted within the frame of general studies of intonational meaning consisting of expressiveness component and informational structure or focus structure component [Halliday, 1967, Crystal, 1969]. Although empirically it is the pitch accent that expresses focus, various authors [Chomsky, 1971, Jackendoff, 1972, Halliday, 1967] insist that focus belongs to the level of Syntax and is represented in the surface structure by means of the Focus-label device.

Thus, studies on focus structure can be divided into two groups:

- syntax-oriented research works
- prosody-oriented research works.

According to the first syntax-based approach syntax plays the dominating role in focus production controlling all the other components [Cinque, 1993, Zubizarreta, 1998, Selkirk, 1986, 1995]. On the contrary, the second approach links focus production with intonation bringing prosody to the dominating position.

Very often focus is being connected directly with the main stress of the utterance [Chomsky & Halle, 1968]. The ways with which focus is linked to the main stress may differ as in English, for example, the main stress is being switched while the languages where such shift is not possible use syntactic movement. As in Greek both main stress shift and syntactic movement are possible, speakers have the opportunity to combine both strategies adding a personal touch in marking focus structure [Baumann, Grice Steindamm, 2006].

In many languages focus may influence prosody changing the tonal structure of the utterance, prominence and phrasing. Despite all these the relation between focus and different types of prosody is not as clear as the relation of focus with phrasing [Frota, 2000].

Syntax-based approaches

Within the framework of the generative linguistic theory narrow focus is usually understood as an operator responsible for the quantifier movement making the focused element stand out being moved to a different place in the utterance [Svolacchia, 1995].

Many linguists define focus as a syntactic category that is being moved to the specifier of the focus phrase [Brody, 1990, Rizzi, 1997]. In the Minimalist theory focus is being related to feature checking [Frascarelli, 2000, Horvath, 1995]. According to this theory elements in focus are moved to the specifier of the Focus Phrase situated in the left periphery, either in obvious or hidden manner. This does not mean that the Focus Phrase should be always placed in the same way but possible interpretations of right-side movement are still under discussion. Some linguists interpret movement to the right as a non-syntactic phenomenon which does not follow the movement rules [Zubizarreta, 1998].

Focus as syntactic phenomenon can be related in a certain way to such prosodic means as pitch accents. Such a fact shows that prosody may define the place of elements in focus. Focus consists of the most prominent on the rhythmic level element to which the main stress is being moved according to the Nuclear Stress Rule. Such Stress shifts belong to marked strategy of placing focus to the elements being at final position. In some cases scrambling is needed in order prominence to be given to the final element of the sentence. Expressing focus depends on C-command relation between the two phrases.

Intonation-based approaches

The most of recent studies describe focus as PF phenomenon. Generativists describe focus as assigning prominence within the utterance. Even though focus is understood as intonational phenomenon, it is acknowledged that syntax plays a very important role in focus production forming the basis to which rules of prosody are applied. According to prosody-based approaches the prosody mechanisms of focus production are totally independent of syntax. Thus the dominating role of syntax in the grammar hierarchy is being rejected. The idea of prosody being an independent level of expression is based on the cases when relation between syntactic components and tonal structure cannot be unveiled. Tonal structure is the ground of interactions between syntactic and phonological structures [Inkelas & Zec 1990, Nespor & Vogel 1986, Selkirk 1984].

Vallduvy and Engdahl divide languages to plastic and non plastic according to their capability of using prosody for focus production [Vallduvy & Engdahl, 1995]. According to this approach Spanish is considered to be a non-plastic language as far as absence of stress at

sentence level makes production of basic, not marked tonal structure impossible. In such languages focus production is strictly linked with syntax.

According to the theory of prosodic phonology speech is created of a set of hierarchically structured phonological elements. The existence of certain hierarchy in the speech structure is proved by the fact that different phonological rules are being applied to different levels of this prosodic hierarchy (i.e. the “sandhi” phenomenon). Phonological structure of the utterance is adjusted to the phonological hierarchy based on the syntactic structure of the utterance but still remaining independent of it [Lieberman & Prince, 1977].

Later researches in the field of intonation were based on the idea of introducing hierarchical levels in prosody analysis [Selkirk, 1980] though using prosodic categories rather different than the ones used by Selkirk: intonational phrase, phonological phrase, prosodic word, foot and syllable [Beckman & Pierrehumbert, 1986, Hayes, 1989, Nespor & Vogel, 1986, Selkirk, 1984]. Intonational phrases are the biggest phonological entities with phonetically clear cut borders and closely related to the syntactic structure of the utterance [Ladd, 1996]. Pierrehumbert uses tonal characteristics in order to define the borders of the intonational phrase: the boarding tones (high or low) [Pierrehumbert, 1980]. Within the intonational phrase phrasal accent is placed after the nuclear accent. Intonational phrases consist of smaller phonological units, phonological phrases. Phonological phrase can be defined as the first unit in prosodic hierarchy consisting of more than one independent word [Nespor & Vogel, 1986].

Within the framework of intonational phonology intonation plays the main organizing role in speech. Intonational phrases consist of pitch events the meaning of which together with edge tones is very important for intonational phonology. Pierrehumbert in her analysis uses two simple tones High and Low, sequences and different combinations of which form intonational patterns of a language [Pierrehumbert, 1980]. These sequences consist of one or more pitch accents connected by stressed syllables. Pierrehumbert analyzes boundary tones as independent tonal units present at the end of each phonological phrase. The end of each intonational phrase is marked by final tones. The main prominence is always placed at the end of the utterance and expressed by phrase accent.

The central role in intonation analysis belongs to the pitch which is expressed by the Fundamental Frequency (F0). Pitch plays an important role in expressing prominence. Languages are divided in tone and stress languages according to the way pitch is being used. Greek belongs to the group of stress languages as it uses pitch mainly at intonational level while in tonal languages using different tones differentiates the meaning of phonemes, morphemes, words.

Fundamental frequency expresses a sequence of tonal changes at the phonological level. In some languages distribution of pitch accents and intonational patterns defines focus structure: presence or absence of pitch accents works as the mechanism for realization of different focus domains [Selkirk, 1995]. In many languages focus is expressed through pitch peaks although elements in final position are always characterized by pitch peaks despite their role in the informational structure of the utterance.

Semantic-based approaches

The semantic-based approaches study focus as an element of the informational structure of the sentence. In informational structure analysis the most important role belongs to the *new* and to the *old information* being the two poles on which the informational structure of the sentence is based. The studies on informational structure of sentence can be divided into two groups according to their understanding of informational structure as basic notion in the analysis. The first approach can be named *static* while the second one – *dynamic*.

The static approach describes the information structure of the sentence as opposition between such elements as: theme, something already known, familiar and context dependent and, on the contrary, rheme as the part that forwards communication, as the new element, independent of any context.

Dynamic approaches to information structure are based on the views introduced by the theory of *Functional Sentence Perspective* and the notion of *Communicative Dynamism*. Within this framework sentence structure expresses the evolution of information during the process of communication. Thus, each point in the sentence has different level of Communicative Dynamism with accordance to its role in communication progress. Rheme is considered to be the creative communication unit in the sentence as it has the highest rate of Communicative Dynamism.

Both approaches to information structure of the sentence agree in defining the two opposite states of information – new and old, known. Those two axis are present in all theories of information structure although in most of models other components of information analysis are being introduced (see Table 4).

Although as we can see there is no unity between the researchers on the information units used in the analysis, the basic issues discussed are the surface expression of those units, those syntactic placement and their boundaries. Frequently it is the words that become the basic units of such an analysis being the smallest tonal unit having meaning. Intonation plays an important role in analysis of the semantic structure of utterance as it is the brightest although not the unique way of phrasing.

14 Theoretical background

Information unit, as described by Halliday, from semantic point of view combines two functions – the function of new and the function of already known and as for expression it is a *product of interaction between syntax and intonation* [Halliday, 1985: 274-275].

Table 4. Theoretical Organising charts for Information Structure.

Binary	Multi-factor
Firbas 1964, 1966	Halliday 1967
theme/rheme	theme /rheme
	given/new
Dahl 1969	background/focus
Mathesius 1929	Bolinger 1965
topic/comment	theme/rheme, accent
Steedman 1991	presupposition/focus
theme/rheme	Vallduvi 1990
	link/tail/focus
	topic/comment
	background/focus
	context bound/unbound
	context dependent/independent
	Chafe, Prince
	given/new
	topic/comment
	given/new
	Vallduvi & Vilkuna 1998
	theme/rheme,
	0/kontrast

The role of intonation in expressing information structure has been introduced by Bolinger and Jackendoff [Bolinger, 1965, Jackendoff, 1972]. One of the main ideas was that deaccenting, being non-marked, is linked to given information [Hirschberg & Pierrehumbert, 1986]. While the marked placement of prominence on a word is signaling narrow focus [Jackendoff, 1972]. The rheme is linked to high pitch as «*frequently it is marked by stress while the rest of the utterance remains background*» [Vallduvi, 1998: 100].

4 Methodology

In this section the experimental methodology used for the scope of the present study is being described. As our goal is to introduce a dynamic approach to focus the experiments were designed in order to withdraw the interactions between focus and F0 rise as the latter is considered to be its main and most reliable tonal correlate. Here we describe the way our experiments were designed in order to fulfill this purpose: the way our speech material was designed and manipulated during the experiment as well as the subjects who took part in our experiments and the way recorded material was analyzed.

Speech Material and subjects

The speech material for the both parts production experiments presented in this study consists of four three-component sentences, 11 syllables each, in Greek and Russian for the scope of the first part and only in Greek for the second (Table 1).

Table 1. Test sentence syllabic sequences with rhythmic variability of interstress number of syllables in Greek and Russian (broad translation).

Greek	Russian
i me.la.´ni ´ma.lo.ne ti ´ma.na mu “Melany was scolding my mother.”	ma.´ri ´my.la u.nix ix.man.da.´ri.ny “Mary was washing at theirs their mandarins.”
i me.´li.na ´ma.lo.ne ti ´ma.na mu “Melina was scolding my mother.”	ma.´ri.na ´my.la u.nix ix.ma.´li.nu “Marina was washing at theirs their raspberries.”
i me.´li.na mu ´ma.lo.ne ti ´ma.na “Melina was scolding mother.”	ma.´ri.na lo.´ma.la u.nix ma.´li.nu “Marina has broken at theirs raspberries.”
i me.´li.na mu ma.´lo.ni ti ´ma.na “Melina is scolding mother.”	Ma.´ri.na na.lo.´ma.la ix.ma.´li.nu “Marina has broken their raspberries.”

All the sentences were designed so that they consist of syllables with CV structure where C in most of cases was liquid. The material was organized in such manner that the number of syllables composing one of the three stress groups was varying from 1 to 4 respectively (see Table 2).

16 Methodology

In the first production experiment aimed at investigating syllable durations between stress alternations, which define the boundaries of interstress intervals, 2 Athenian and 2 St. Petersburg female speakers, university students in their early twenties, have been recorded.

Table 2. Speech material of the study.

I	me	La	NI	MA	Lo	ne	ti	MA	Na	Mu
Melany was scolding my mother.										
I	me	LI	na	MA	Lo	ne	ti	MA	Na	Mu
Melina was scolding my mother.										
I	me	LI	na	mu	MA	lo	ne	ti	MA	Na
Melina was scolding mother.										
I	me	LI	na	mu	Ma	LO	ni	ti	MA	Na
Melina is scolding mother.										

For the second experiment the recordings were made by 4 female Athenian speakers in their early twenties. In the second part of this experiment the speech material consisted of 3 instead of four productions of each sentence leaving outside the object focus. All the sentences were recorded by 4 female Athenian speakers in their early twenties in 4 repetitions out of which the 2 middle ones were used for our analysis.

Recording and analysis process

For the scope of the both experiments focus was determined in it on the basis of the immediately preceding context as background part of the target-utterance was being formed on the basis of the question made. Thus, the subjects were given 16 cards with one sentence on each: each sentence of the speech material described in the previous section was given four times as four focus elicitations – neutral, S-focus, VP-focus and O-focus – were recorded (see Table 3).

Table 3. Context for the speech material on the basis of target sentence “Melani was arguing with my mother”.

Question	Type of focus
Who was arguing with your mother?	Narrow focus on S
What was Melani doing?	Broad focus on VP
With whom was Melani arguing?	Narrow focus on O

For both experiments all the recordings were made in a quiet room through a microphone directly connected to the PC. The speech samples were segmented on the basis of simultaneous visual displays of the

waveform, wideband spectrograms and F0 contour using the PRAAT speech analysis system [Boersma & Weenik, 1992]. For each test syllable F0 minimum and F0 maximum of the pitch accent were automatically extracted.

The first experiment was aimed at examining interactions between focus domain and rhythmic structure. As interstress intervals being the basic elements of rhythmic structure are used in classifying languages to stress-timed and syllable-timed syllable-timed, and while within this framework Greek is reported as an “unclassified” language [Dauer, 1983], cross-language analysis was conducted with the help of data from Russian (see Table 1). The speech material was recorded twice in normal tempo and during its analysis each syllable’s duration has been measured as well as each stress group’s duration has been also calculated. So, for each of the two languages the recorded material for the first experiment included 176 measurements (4 utterances x 2 speakers x 11 syllables x 2 repetitions).

In the first part of the second experiment for each test syllable F0 maximum and F0 minimum of the pitch accent were automatically extracted. As in this experiment it was not our goal to consider stress group length we have calculated the mean values of all 4 utterances produced by our 4 speakers having separated the 4 focus placements. So, as a result we had for each focus placement we made 1408 measurements (4 utterances x 4 speakers x 11 syllables x 4 repetitions x 2 measurements).

During the second part of the second experiment only two middle repetitions have been used. Measurements consisted of F0 maximum for the whole utterance and two F0 minimums placed in the valley before and the valley after it. Each pitch measurement was accompanied by its timing data in order for the pitch speed to be calculated. So, for each focus placement we had 192 measurements (4 utterances x 4 speakers x 2 repetitions x 6 measurements). For calculating the rising and falling tone speed the following formula has been used:

$$V = \frac{F0_{\text{peak}} - F0_{\text{low}}}{T_{\text{peak}} - T_{\text{low}}}$$

5 Results

In this section the results of the analysis carried out for the purpose of the present study are presented. A detailed analysis of the F0 events during each syllable of the recorded Greek material has been carried out while the rhythmic structure of Greek syllables is examined in contrast with corresponding data from Russian.

The results of the first experiment are presented below in Figures 1-6. In Figure 1 we observe that the stressed syllables are longer than the unstressed ones in Greek ($p < 0.0001$) but this is hardly the case for Russian where the duration difference between stressed and unstressed syllables in our material does not reach a significance level. It should be noticed that this is not an optional context for a comparison between stressed and unstressed syllables since syllables have different positions and structure, especially in Russian the unstressed syllables of which have a complex structure but nevertheless do not overcome the duration of the stressed syllables. This means that in similar conditions the stressed syllables of Russian are considerably longer than the unstressed ones, much like the way it is in Greek.

In Figure 2, a descending duration pattern can be observed, according to which the more the syllables in a stress group the less their respective average duration, which is evident in both Greek and Russian. In Figure 3, a reverse duration pattern to the one of Figure 2 is evident, according to which the more the syllables per stress group the longer the duration of the respective stress group. Comparing the results shown in Figures 2 and 3 we can assume that a tendency for keeping the duration of the stress group from changes is observed in both languages though it is still very far from true isochrony.

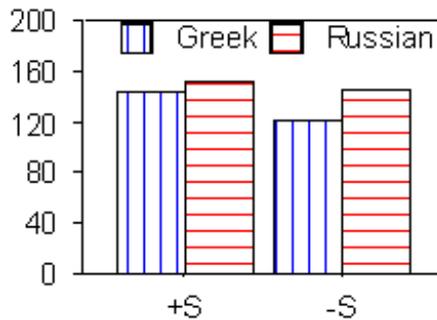


Figure 1. Average syllable durations as a function of stress (+stress/-stress) in Greek and Russian.

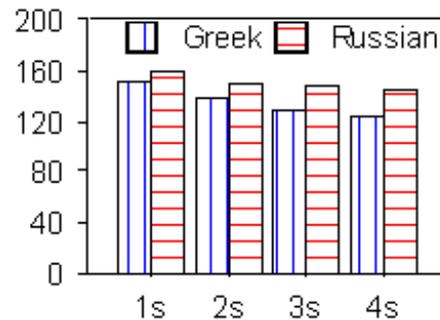


Figure 2. Average syllable durations as a function of syllables per stress group in Greek and Russian.

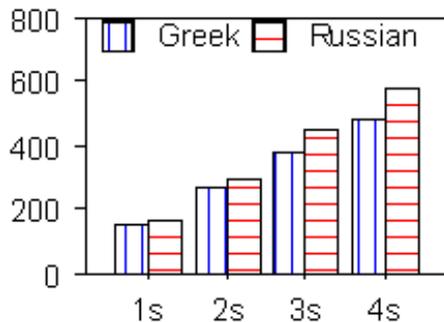


Figure 3. Average stress group durations as a function of syllables per stress group in Greek and Russian.

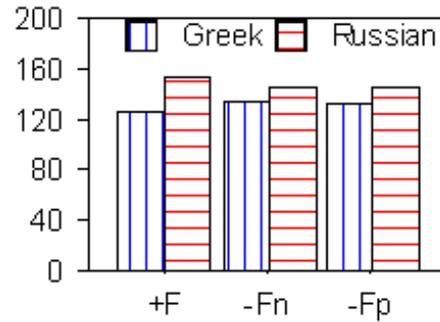


Figure 4. Average syllable durations as a function of focus (+focus/-focusneutral/-focuspost position) in Greek and Russian.

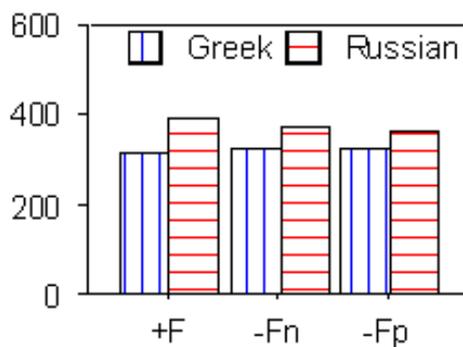


Figure 5. Average stress group durations as a function of focus (+focus/-focusneutral/-focuspost position) in Greek and Russian.

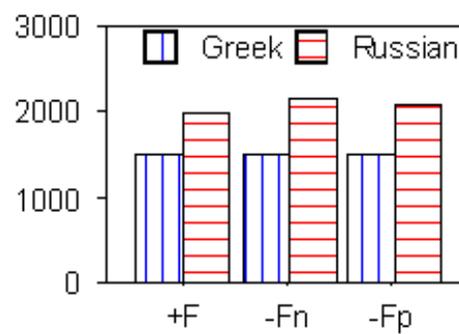


Figure 6. Average utterance durations as a function of focus (+focus/-focusneutral/-focuspost position) in Greek and Russian.

20 Results

In Figure 4, there appears a fairly even duration pattern among syllables with different focus conditions in both Greek and Russian, i.e. in focus and out of focus, be that neutral (-Fn) or post focus (-Fp). There are hardly any effects of focus on either stress groups (Figure 5) or utterances (Figure 6) and this is evident in both Greek and Russian.

Table 5. Comparative data for rhythmic taxonomy.

Durations	Greek	Russian
Syllable durations as a function of stress	Significant $t(115)=5.758$, $p<.01$	Not significant $t(118)=1.474$, $p>.05$
Syllable durations as a function of syllables number in the stress group	Highly significant $F(3,113)=7.157$, $p<.01$	Not significant $F(3,116)=1.830$, $p>.05$
Stress group durations as a function of syllables number in the stress group	Significant $F(3,87)=452$, $p<.01$	Significant $F(1,87)=44$, $p<.01$
Syllable durations as a function of focus assignment	Not significant	Not significant
Stress group durations as a function of focus assignment	Not significant	Not significant

Summing up, both Greek and Russian seem to have similar rhythmic structures, at least with reference to interstress intervals examined in the present study. On the other hand, both languages show minimal isochrony not enough for any of them to be taxonomized as a stress-timed language (see Table 5).

As according to the results of our first experiment changing focus domains seems not to affect average durations of syllables and stress groups in a significant way. Another candidate for the place of focus correlate was F0 manipulation, so second experiment was conducted in order to investigate tonal rise and fall accompanying focus production and possible connection between F0 rates and duration. The results of the first part of our second experiment are presented in the Figures 7-10.

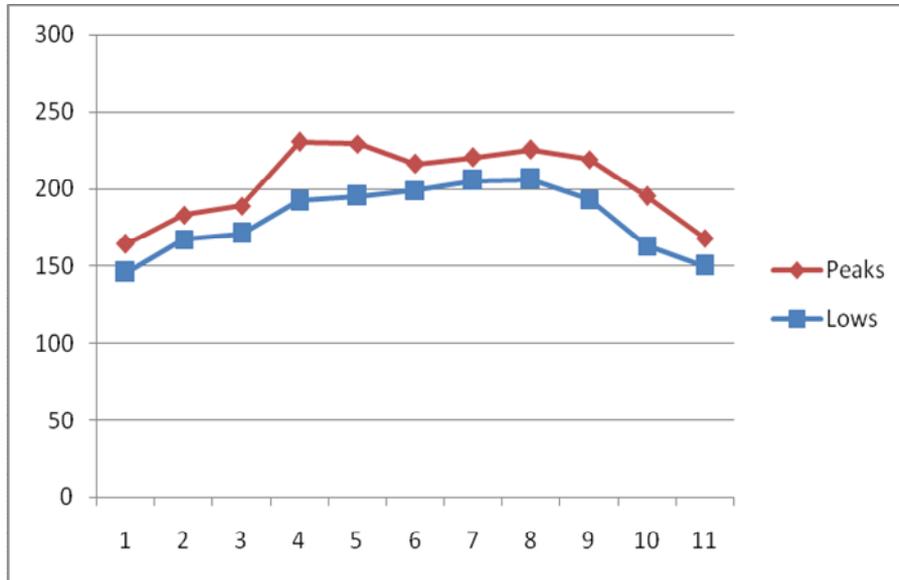


Figure 7: F0 max and F0 min means during the neutral realization.

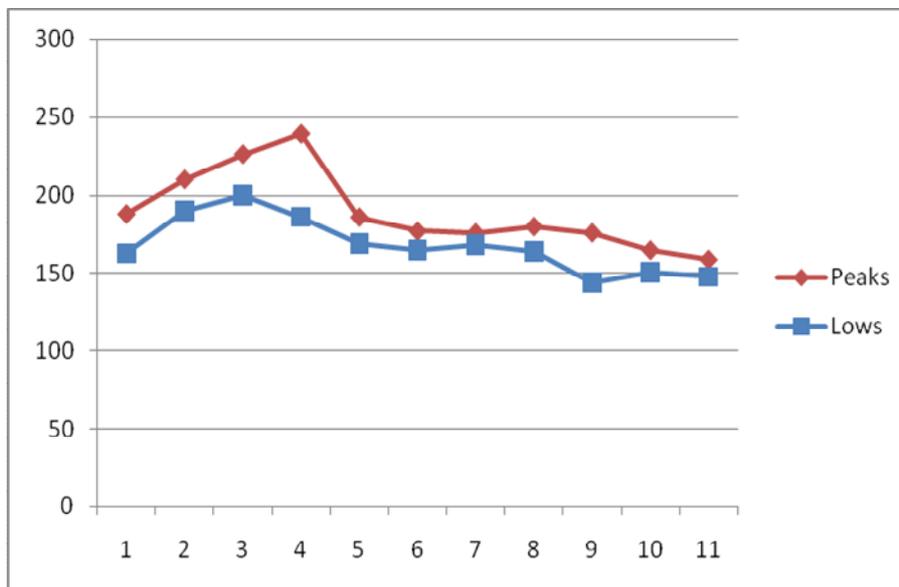


Figure 8: F0 max and F0 min means during the Subject Focus realization.

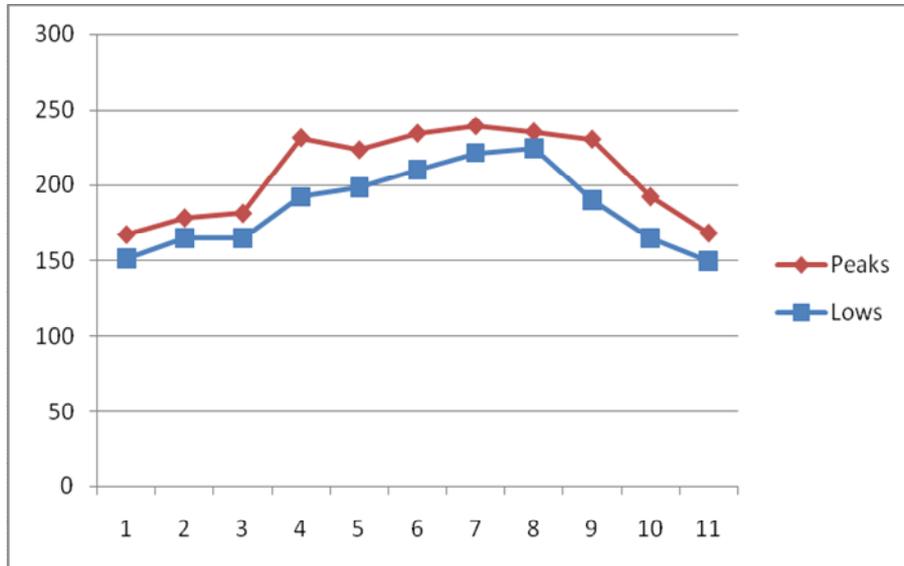


Figure 9: F0 max and F0 min means during the VP Focus realization.

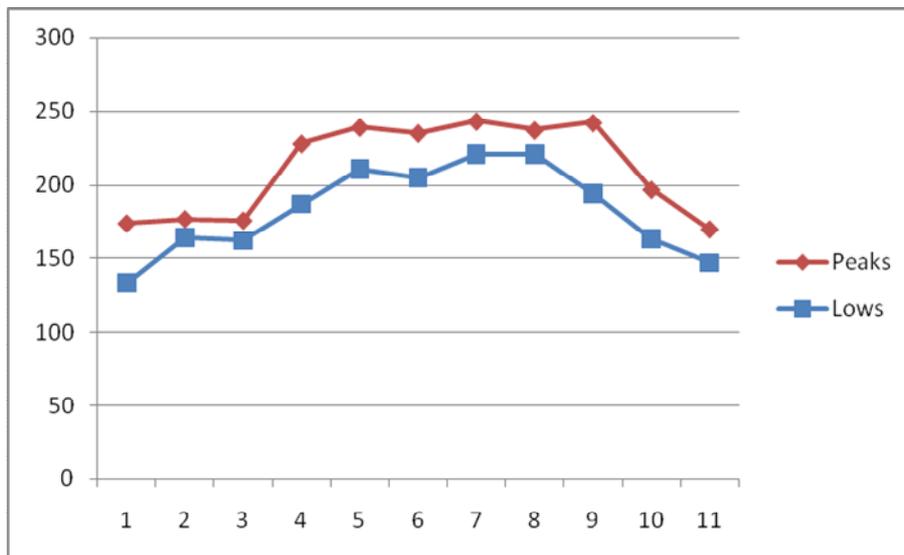


Figure 10: F0 max and F0 min means during the Object Focus realization.

The first analysis of the main Greek material showed that while focus was expected to have a large impact on the tonal structure of the utterance

introducing the tonal expansion in the focal area accompanied by “flattering” of the tonal curve forming “background area”, quite frequent were the cases when no global compression has been observed (compare figures 7, 9 and 10).

It should be stressed that most of clear cut cases of focal tone rise-fall have been noticed for focus on the first constituent (Subject) (see figures 8 and 11).

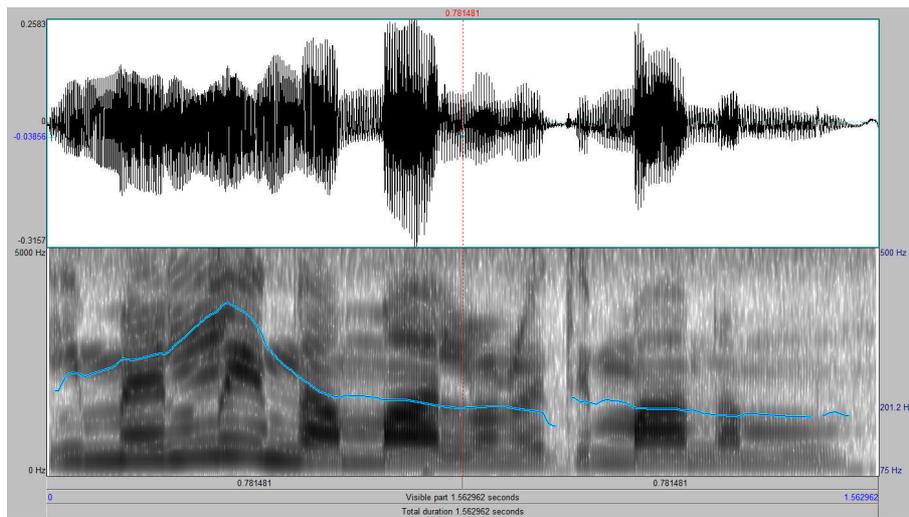


Figure 11: Waveform and F0 trace for the sentence “i me.LI.na MA.lo.ne ti MA.na mu” with Subject focus placement.

On the contrary, cases of focus on VP or Object were found much similar to those of neutral realizations as far as tonal structure was concerned (see figures 12 and 13).

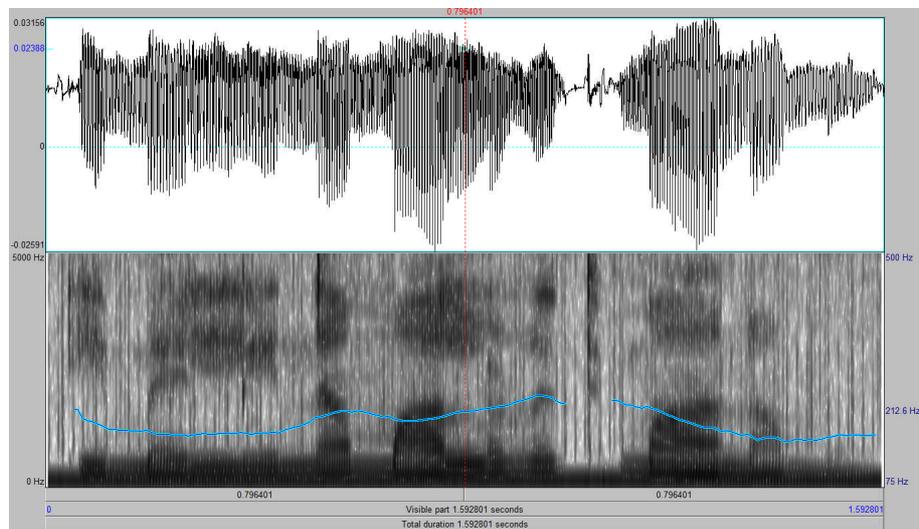


Figure 12: Waveform and F0 trace for the sentence “i me.LI.na MA.lo.ne ti MA.na mu” with VP focus placement.

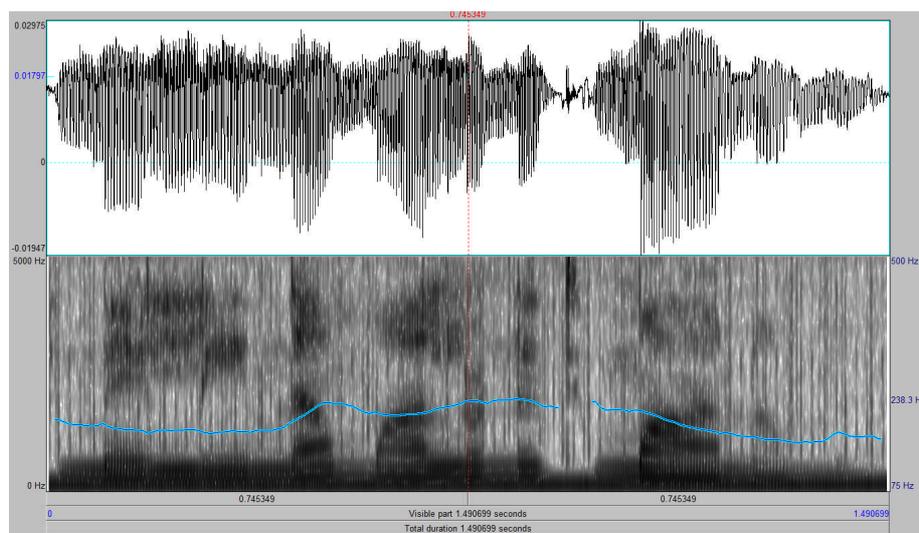


Figure 13: Waveform and F0 trace for the sentence “i me.LI.na MA.lo.ne ti MA.na mu” with Object focus placement.

Since local tonal expansion and global tonal compression were not observed very clearly in most of cases in the examined material, it could be assumed that there should be another factor giving enough prominence to the tonal movement without compressing the rest of the tonal structure. The F0 rise did not seem to be an obligatory cue for focus production.

Table 6. Mean values for F0 peak and valley as well as for the rising and falling tone speed.

Focus type	Peak, Hz	Rising slope	Falling slope	Valley, Hz
Neutral	284	0,0007	0,0004	243
Subject	345	0,0004	0,0007	189
VP	325	0,0004	0,0005	217
Neutral	285	0,0004	0,0001	221
Subject	369	0,0005	0,0009	202
VP	332	0,0004	0,0005	232
Neutral	276	0,0004	0,0004	217
Subject	371	0,0006	0,0008	208
VP	324	0,0003	0,0005	226
Neutral	299	0,0004	0,0005	209
Subject	367	0,0005	0,0008	217
VP	333	0,0005	0,0007	226

A parameter that would be probably more reliable for focus production is the slope, the speed with which the tone either rises or falls or combination of those two factors. Following this hypothesis the second part of our experiment was aimed at finding the rising tone and the falling tone speed.

Taking into consideration the fact that no major difference between VP focused and O focused realizations has been observed it was decided to skip O-focused realizations for the second part of the experiment the results of which are presented in Table 6.

As it was expected the utterances with focus had much higher peak F0 rate than the neutral ones while the F0 valley range following the peak was changing much less. On the other hand the rising tone speed was not changing much in cases of focus placement while the difference in falling tone speed was remarkably high. It is seen better if we take the average rising and falling speed that were observed for the speakers in all four sentences (see figure 14).

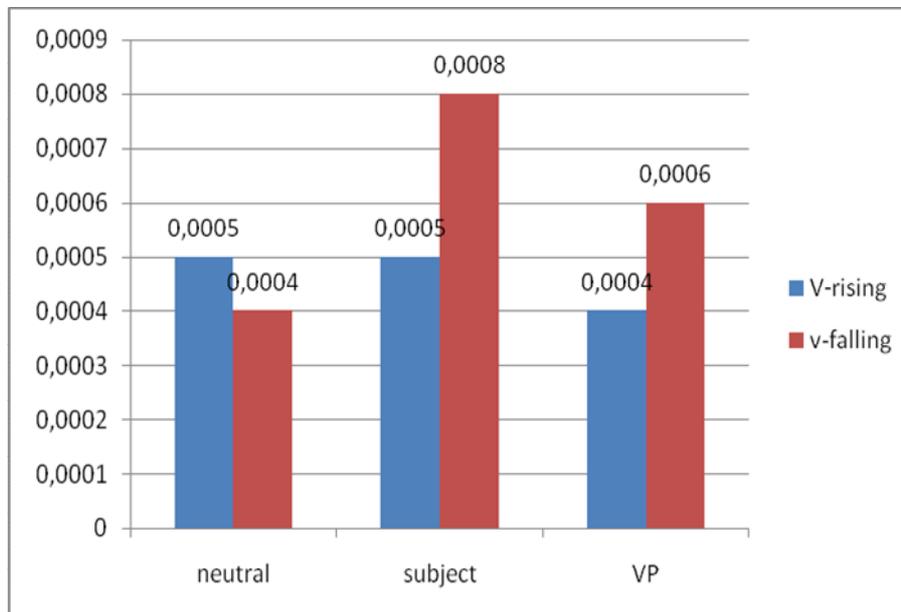


Figure 14: Rising and falling tone speed rate averages in cases of different focus placement.

As our material has shown local tonal expansion and global tonal compression are not observed in most of cases so clearly, the fact that makes us think that there should be some other parameter making the tonal movement prominent enough without compressing the rest of the tonal structure. F0 rise seems to be not an obligatory cue for focus production, the fact that agrees with the observations made by M. Heldner for the case of focus perception in Swedish [Heldner, 1998].

6 Discussion

The following discussion will address the question of applying complex analysis to focus stated in the introduction based on the results of the data analyses described in the previous section. In the present study rhythmic and fundamental tonal structures have been investigated with relation to focus structures. As a result of the experiments carried out the relation of mutual dependency between rhythmic, tonal and focus structures has been revealed supporting the multifactor analysis as the only meaningful approach for language studies.

It is not news that focus contributes much to forming F0 pattern of the whole utterance affecting the contour [Pierrehumbert, 1980], on the contrary a unite matrix of focus correlates yet has not been created. In composing such matrix multifactor units in analysis of focus should be used. Talking of the focus correlates matrix we do not mean trying to build a network of direct mappings between communicative meaning and invariant acoustic correlates as such direct connection does not exist due to the following mechanisms: articulatory implementation, language-specific target assignment and parallel encoding of multiple communicative functions [Xu, 2005].

Local tonal expansion combined with global compression especially in the post-focus area widely acknowledged as focus-indicator by the linguists [Xu, 1999, Xu et al., 2004, Xu, 2005, Botinis et al., 2000, Botinis, 2003, Rump and Collier, 1996, Mixdorff, 2004]. Although according to the results of the present study it seems that the F0 rise combined with compression of the tonal contour is not an obligatory and thus reliable enough cue for focus production in Greek (Fig. 7,9,10). Talking about F0 peaks and F0 lows, the results of the present analysis showed that focus has little impact on F0 minimum affecting only F0 range at the peak point (Tab. 6).

In the first part of the experimental study we examined the duration component and observed the negligible effects of focus on different prosodic units, in the first place on syllable, stress group and utterance which is in accordance with earlier research [Botinis 1989, Fourakis et al. 1999, Botinis et al. 2002]. Russian seems to behave similar to Greek in this respect, according to the present results, which should however be further corroborated before preliminary conclusions are drawn.

In the second part of our experimental study we examined the combination of F0 rate change and duration. As it is known from biophysical data on speech production the maximum speed of pitch change increases in direct proportion to the size of the change, as well as the time taken to achieve a pitch change also increase with the size of the change [Ohala and Ewan, 1973, Fujisaki, 1983, Xu and Sun, 2002].

The results of our experiment connecting time and F0 change to focus indicate that the increase of the falling tone speed rate was accompanying focus application in all the cases found in our speech material. Here we presented some first data on the rising and falling F0 speed according to which the speed with which F0 falls is being increased in cases of focus application. Of course the importance of F0 fall for focus is by no means news, but it should be stressed that previous similar findings have been largely drowned by the conventional view which puts all the emphasis on the acoustic patterns of the focused word itself [Xu, 1999]. In the present study we introduced a complex approach to focus in which acoustic and tonal characteristics of all the elements in the utterance are examined. The fruitfulness of such a complex approach to focus was proved by the results of this first analysis showing that the increase of the falling tone speed was present even in cases of great similarity between tonal curves, the fact that makes us believe in the special role of tonal speed in focus production.

It should be mentioned though that the F0 fall examined in this study is likely to be only part of the post-focus F0 events as all the post-focus components need to be considered while segmental and asyllable anchoring points for peaks and valleys should be also considered in the further study.

7 Conclusions

The results of the present study reveal the necessity of studying focus structures in terms of bringing communicative function together with the correlates in order to create a unite matrix of multifactor units for focus production and perception. As it was shown in the first part of our experimental study, rhythmic structure alone was not affected by focus application in a significant way. On the other hand, focus was found to significantly influence falling tone speed rate which brings the first pro for the multifactor analysis of focus uniting in one unit duration and speed rate change.

With reference to rhythmic taxonomy, Russian has been traditionally classified as a “stress-timed” language whereas Greek is reported as an “unclassified” language [Dauer, 1983]. However, Greek and Russian were found to have similar rhythmic structures, at least with reference to interstress intervals presented in this paper, which is in accordance with Dauer’s conclusions that there is no clear-cut distinction between stress-timed and syllable-timed languages as most analyzed languages show some degree towards isochrony. Still, both Greek and Russian show minimal isochrony for any of these languages to be taxonomised as a stress-timed language.

Another question about rhythmic structure and isochrony is the relevant prosodic units with reference to the domain and attachments of stress groups [Bouzon & Hirst, 2004]. Obviously considerable research is needed, especially with reference to perceptual classification of rhythmic units before a basic understanding of rhythmic functioning has been reached.

Our further experimentation will involve collecting production data from more speakers as well as testing the perceptual relevance of the falling tone speed rate as correlate of focus in all possible positions in the simple utterance. Furthermore new experiments will involve more detailed examination of the F0 movements in order to collect empirical data on the range of the focal rise and fall as well as on the changes in duration and amplitude accompanying focus production.

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