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THE PHONETICS OF METRICS

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ABSTRACT

The purpose of this investigation is to test whether there is a connection between metre and the prosodic structure of a language. If a correspondence exists, the same meter should be realized in a phonetically different way in languages with different prosodic systems, and the differences in the phonetic realization of the metre should be explainable on the basis of the differences between the prosodic systems. The study begins with an examination of the realization of the trochaeic pattern (bisyllabic feet accented on the first syllable) in Finnish, Estonian, Swedish, and Lithuanian. This is followed by a consideration of the relationship between metric feet and poetic lines. Stress-timing is illustrated with reference to Icelandic.

INTRODUCTION

The question of the relationship between the prosodic structure of a language, the metric structure of poetry created in that language, and the rhythm of music has intrigued me for a very long time. I first became aware of it as a child, when I was a fairly advanced student of the piano and tackled compositions by Franz Liszt. His Hungarian rhapsodies contain so-called syncopated measures in which a short note on the beat is followed by a long note in what would normally be an unstressed position. Many pianists, including my (Russian-born) piano teacher, shift the stress to that long note. Instinctively I felt this to be wrong. When I learned something about the language, it became clear to me why. Hungarian words are always stressed on the first syllable, but duration is contrastive in both stressed and unstressed syllables. There are many Hungarian words with a long second syllable, but there are no Hungarian words with stress on the second syllable. The rhapsodies utilize folk tunes—associated with the words of folk songs—and the so-called syncopated measures really represent Hungarian words

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with a stressed short first syllable and an unstressed long second syllable. The music follows the text; the rhythm of music is the rhythm of the language.

Hungarian is a Finno-Ugric language, as is Finnish—and Estonian, the language I speak natively. One of the characteristics of languages like Estonian, Hungarian, and Finnish is the contrast between short and long stressed syllables—a contrast that languages like English and Russian do not possess. In the Finno-Ugric languages, a stressed open syllable can end on a contrastively short vowel. In English and Russian, on the other hand, stress is accompanied by lengthening; and conversely, long syllables are perceived as being stressed (and I suspect this to be the reason for shifting the stress to the long second note in the syncopated measures of Liszt's rhapsodies—by players who are speakers of these Indo-European languages!).

On a more serious plane, observations such as these have led me to ask a number of questions concerning the relationship between the prosodic structure of a language and the metric structure of poetry created in that language. First and foremost: is it really true that such a relationship exists? If it does, how is it manifested phonetically? How could this manifestation be explored using experimental phonetic techniques?

These questions provide the background to the investigation of the phonetics of metrics that I have been engaged in for a number of years.[1] My general approach has been acoustic analysis of orally produced poetry recorded by several speakers of languages with different prosodic structures. I have worked primarily with trochaeic and dactylic metres, but I have also sampled the realization of the haiku form in different languages, and have looked at the structure of the poetic line in certain others. One reason for selecting these languages was their prosodic diversity. Another reason for inclusion of a language in this particular study was my own relative familiarity with the prosodic structure of the language.

Most of the languages analyzed during the study are spoken around the Baltic Sea. A further reason for selecting this group was my interest in language contact. There is some reason to believe that the languages constitute a "Sprachbund"—a language convergence area, where historical heterogeneity is gradually being replaced by typological homogeneity [1].

The languages discussed in some detail in the present context are the following.

Lithuanian—a language whose prosody includes contrastive tone, contrastive duration, and free stress

Estonian—a language with contrastive duration of vowels and consonants, with a three-way contrast in the first (stressed) syllable of disyllabic (and polysyllabic) words and a two-way contrast in unstressed syllables

[1] Since 1988, this research has been supported by the National Science Foundation under Grant No. BNS-8719891.

Finnish—a language closely related to Estonian, with contrastive duration of vowels and consonants in any syllable and with fixed stress on the first syllable

Swedish—a language with stem stress and with contrastive tone in disyllabic sequences; stressed syllables are long, consisting either of a short vowel and long consonant, or a long vowel and short consonant

Icelandic—a language with syllable structure and stress similar to Swedish, but without contrastive tone.

These languages offer rich possibilities for studying such questions as the influence of presence or absence of tone on the duration of stressed and unstressed syllables, the effect of number of syllables on the duration of a metric foot, and the relationship between syllabic quantity, duration of metric feet, and the rhythmic structure of a poetic line. (For references and bibliographies see [1-9].)

PROSODY AND METRE

In the following discussion I am using the term "prosody" in two different senses depending on context. The prosodic (or suprasegmental) structure of a language means here the roles stress, duration, and tone play in the production of words, determining their lexical meaning [10].

Stress denotes greater prominence relative to preceding and/or following speech material, usually associated with greater articulatory effort and manifested acoustically as increased intensity. The other phonetic correlates of stress may differ in various languages, but they frequently include greater duration and higher pitch. Languages can have fixed stress on one of the syllables of a word, in which case the function of stress is identificational: shifting stress to another syllable changes a word to a non-word. Other languages can have movable stress: the meaning of a word can be changed by changing the placement of stress.

Duration can be a phonetic correlate of stress, or it can be independently contrastive (in which case it is referred to as "quantity"). Languages may differ as to the scope of quantity oppositions. In some languages, vowel duration can be contrastively short or long in stressed syllables; in others, vowel duration is contrastive in every syllable. Consonant duration can be contrastively short or long in intervocalic and final position. I am not aware of any languages in which consonant duration would be contrastive in absolute initial position (apart from cases containing a morpheme boundary, such as the Russian word *vvesti* meaning "to introduce," where the first *v* is a separate morpheme meaning "in" or "into").

The term "tone" refers to the use of fundamental frequency of the sound wave (perceptually, pitch) to distinguish between lexical items. Chinese would be a classical tone language. The domain of tone may be a syllable or a word; a language may have contrastive tone on every syllable of a word, or there may be

a single tone associated with each word. In many languages, fundamental frequency contrasts occur only in association with stress.

All these features may be employed at the word level to contribute to the lexical meaning of a word in the same way as do the speech sounds (vowels and consonants) of which the word is composed. The features are also present at higher levels, such as a sentence and a paragraph; in this case they modify the meaning of a sentence without changing the lexical meaning of any of its constituents.

The prosodic features of stress, quantity and tone are often referred to as suprasegmental features. They are part of the phonology of a language; their phonetic manifestation may differ from language to language, but in a general sense, it is possible to compare languages by referring to the contrastive role played by each of the prosodic features in its phonological structure.

The term "prosody" is also traditionally used to refer to styles of versification, especially to rhythmical patterns manifested in verse. A more specific term for these patterns is metre. Four metrical systems are generally discriminated: the syllabic, the accentual, the accentual-syllabic, and the quantitative.

At a very superficial level, the metrical systems could be characterized as follows. The syllabic metre counts the number of syllables in a poetic line. The accentual metre specifies the number of accents per line; the number of syllables may vary. The accentual-syllabic metre is basically a tightening of the accentual metre by specifying both the number of accents and the number of syllables; accented and unaccented syllables combine into several kinds of metric feet, and lines are composed of a fixed number of metric feet. In quantitative metre, durational rather than accentual feet are measured, and each foot consists of a particular pattern of long and short syllables.

FORMULATION OF THE TASK

The purpose of the investigation is to test whether there is a connection between metre and the prosodic structure of a language. If a correspondence exists, the same metre should be realized in a phonetically different way in languages with different prosodic systems, and the differences in the phonetic realization of the metre should be explainable on the basis of the differences between the prosodic systems.

What is being investigated here is not an abstraction, but the actual phonetic realization of different metres in different languages. Phonetic realizations of utterances are the only aspect of language directly subject to observation; and experimental phonetics provides a point at which metrical theories can be tested with respect to at least one kind of objective reality.

The methodology of the investigation was the same for all languages. Recordings were made of readings of two trochaeic poems, two dactylic poems, two poems in free verse, and some poems reflecting the oral tradition of a particular

language and culture, e.g., fourteen stanzas from the *Hávamál* for Icelandic, two folksongs from *Kanteletar* for Finnish. The number of speakers was from one to six. The recordings were made at university phonetics laboratories or radio stations in the respective countries. The tapes were analyzed at The Ohio State University using standard acoustic-phonetic techniques. In the first stages of the study, the voiceprint spectrograph was the primary analysis instrument, while the more recent work has been done with the Kay 5500 spectrograph.

Measurements have been made primarily of the duration of metric feet, poetic lines, and pauses between the lines. However, in some cases syllable durations were likewise measured; and for the tone languages, Lithuanian and Swedish, fundamental frequency measurements were also made. The present article offers results of my own work; no attempt will be made to provide a history of the phonetic study of metrics. The acoustic-phonetic study of orally produced poetry appears to be a relatively new field, and there exist few published data with which my results could be compared.[2]

I will start with the realization of the trochaeic pattern in Finnish, Estonian, Swedish, and Lithuanian. This will be followed by a consideration of the relationship between metric feet and poetic lines. Stress-timing will be illustrated with reference to Icelandic. Part of the material has been presented elsewhere and in some cases has already been published, but a considerable part consists of newly acquired data [2, 4, 5, 12, 13].

In classical quantitative verse, the trochee is a metrical unit consisting of a long syllable followed by a short syllable. The term has been adopted into English for the accentual foot consisting of a stressed and an unstressed syllable. (For a discussion of metrical theory as applied to English, see [14].) This study follows the convention of calling disyllabic metric feet trochaeic, when they are accented on the first syllable, disregarding for the moment the fact that Finnish and Estonian words may start with a stressed short syllable.

TROCHAEIC PATTERNS IN FINNISH

Results from a study of Finnish will be reported first.[3] The two trochaeic poems that were selected were "Vastavirtaan" by Juhani Siljo and "Kapina" by Lauri Viita. The first consists of thirty-two five-foot trochaeic lines, arranged into three stanzas. The second contains thirty-eight four-foot lines, arranged into four stanzas. (The last line of the poem contains only two metric feet.) The corpus thus consists of 157 + 152 = 309 metric feet, produced by six readers, for a total of 1854 metric feet.

[2] However, similar research is now going on in Stockholm [11].

[3] The Finnish materials were recorded in Turku, Finland, in September 1988.

Table 1. Number of Metric Feet Belonging to Various Metric Foot Types in Two Finnish Trochaeic Poems, "Vastavirtaan" and "Kapina"

Poem	Short-short	Short-long	Long-short	Long-long	Monosyllabic
Vastavirtaan	15	28	50	55	9
Kapina	18	32	46	54	2
Total	33	60	96	109	11

Since in Finnish, syllables can be contrastively short or long in both positions in the trochaeic foot, four metric foot types are possible. The two poems also contained a number of lines that ended with a monosyllabic foot. The distribution of metric feet according to syllable duration is shown in Table 1.

Strictly speaking, only the long-short metric feet should be considered trochaeic. There are relatively few short-short metric feet. Together, the metric feet starting with a stressed short syllable (SS and SL) constitute 30 percent of the total; metric feet with a long first syllable dominate, with 70 percent of the total number of metric feet.

The durations of all metric feet were measured, and averages were calculated separately for all six speakers. Table 2 presents average durations of metric feet in two positions, line-medial and line-final. Initial metric feet were omitted from the calculations because of possible boundary effects. Final feet were treated separately, in order to establish the amount of anticipated pre-boundary lengthening.

One interesting fact emerges from the table: metric feet consisting of one short and one long syllable have the same duration, regardless of the order of the syllables within the foot. In other respects, one may conclude that there is no isochrony present in these trochaeic lines. The duration of a metric foot depends on the duration of its constituent syllables, and the duration of the metric foot increases systematically with the addition of syllabic length. In a separate paper [3], I have argued that Finnish behaves like a classical mora-counting language, in which a mora has a measurable phonetic manifestation in the form of duration.

Another fact worth noting is that in final position, metric feet of all types receive a comparable amount of lengthening, so that the relationships among them remain the same.

TROCHAEIC PATTERNS IN ESTONIAN

The situation is drastically different in Estonian—a closely related Finno-Ugric language. The analyzed Estonian materials consist of two poems, one trochaeic, the other in free verse. (For more details, see [12].) The trochaeic poem was

Table 2. Finnish Poetry: Average Durations, in Milliseconds, of Metric Feet in Two Finnish Poems Read by Six Speakers

	Medial Position				Final Position				
Speaker	SS	SL	LS	LL	SS	SL	LS	LL	Monos.
KW	357	445	452	565	471	627	537	682	400
PL	304	379	424	493	365	484	501	586	274
KR	416	500	493	638	521	554	580	727	382
KT	297	403	394	501	320	474	445	616	378
MM	274	340	340	428	356	397	422	515	238
IR	289	363	350	443	306	392	408	499	252
Average	323	405	409	511	390	488	482	604	321
% increase in duration					20.7	20.5	17.8	18.2	

Note: SS = metric feet with two short syllables; SL = metric feet with a short first syllable and a long second syllable; LS = metric feet with a long first syllable and a short second syllable; LL = metric feet with two long syllables; Monos. = monosyllabic final metric feet.

"Kinni hoidmas" by Paul-Eerik Rummo, read by five speakers.[4] The poem consists of 28 five-foot lines, arranged into four stanzas. The last metric foot was monosyllabic in each case.

The Estonian metric feet comprise three metric foot types that are identical with Estonian disyllabic word types labeled Quantity 1 (Q1), Quantity 2 (Q2), and Quantity 3 (Q3). The words in Q1 have a short open first syllable, a single intervocalic consonant, and a half-long second syllable (for a recent overview of Estonian quantity studies, see [15]). The words in Q2 have either a closed first syllable (ending in one or more consonants) containing a short or long (but not overlong) vowel followed by a short germinate or a cluster equivalent to a short geminate, or, in the case the first syllable is open, contain a long vowel or a short diphthong. The first syllable of words in Q3 contains one or more overlong speech sounds: either an overlong vowel or diphthong, or a short or long vowel (or diphthong) followed by a long geminate or a consonant cluster equivalent to a long geminate.

In addition, Estonian disyllabic words are characterized by a durational pattern that involves the ratio between the durations of the two syllables: the duration of the second syllable decreases as the duration of the first syllable increases. A short first syllable is followed by a half-long second syllable, with a ratio of

[4] The Estonian materials were recorded in Tallinn, Estonia, in February 1989.

approximately 2:3; words with a long first syllable have a ratio of approximately 3:2; and words with an overlong first syllable have a ratio of approximately 2:1.

Metric feet in Q1 are comparable to Finnish Short-short metric feet; those in Q2 and Q3 are both comparable to the Finnish Long-short metric feet. There are no disyllabic patterns that would correspond to the Finnish Short-long and Long-long foot types. The distribution of metric feet among the three Estonian quantities is shown in Table 3.

As was the case in Finnish, there were some metric feet with a short first syllable (i.e., in Q1) and a somewhat larger number in Q2. Most of the metric feet were in Q3, with an overlong first syllable and a short second syllable. Three metric feet were not assigned to a quantity category; they consisted of the third syllable of a trisyllabic word followed by an unstressed monosyllabic function word.

The second poem was the free-verse poem "Ainult kaasa minna" by Jaan Kaplinski. Disyllabic words in Q2 and Q3 occurring in this poem were measured for two speakers when it became necessary to compare the results obtained from the first poem with measurements made from a poem not cast in a rigorous trochaeic form.

Initial feet and final monosyllabic feet were not included at this time. Table 4 presents results of measurements made from medial metric feet [12].

Table 3. Number of Metric Feet Belonging to Q1, Q2, and Q3 Types in an Estonian Trochaeic Poem

Q1	Q2	Q3	Unassigned	Monosyllabic
18	25	94	3	28

Table 4. Average Durations, in Milliseconds, of Medial Metric Feet in an Estonian Poem Read by Five Speakers

Speaker	Q1	Q2	Q3
1	321	443	520
2	348	484	523
3	363	547	594
4	282	480	475
5	337	507	514
Average 1-5	330	492	525

Note: Q1 = metric feet in short quantity, Q2 = metric feet in long quantity, Q3 = metric feet in overlong quantity.

These results were somewhat surprising. On the basis of our knowledge of Estonian quantity, one would expect the absolute durations of the metric feet to increase with a higher quantity degree. Only Speaker 1 conforms to the expected pattern; for the other speakers, the durations of metric feet in quantities 2 and 3 were very similar, and in one case (Speaker 4), the average duration of Q2 metric feet was actually greater than the average duration of metric feet in Q3.

This apparent neutralization of the difference between the durations of metric feet in quantities 2 and 3 seemed counterintuitive: there is no question but that in the mind of the native listener, words in Q2 and Q3 remain distinct even within a trochaeic line. One possible way in which this difference might be manifested is the ratio between the syllables constituting the metric feet. The durations of the individual syllables were measured, and ratios between the durations of the two syllables were calculated. These ratios are included in Table 5. As was shown on Table 4, the absolute durational values of metric feet differed considerably in readings made by different speakers. In order to eliminate the effects of different tempo, I calculated the duration of first and second syllables of metric feet in quantities 2 and 3 as percentage of the duration of the metric foot. As becomes obvious from the table, the relative durations of the two syllables are the same for all speakers, regardless of differences in tempo; all speakers distinguish between the two quantity types with respect to the ratio between the first and the second syllable.

It appears that a certain amount of isochrony is indeed present with regard to the long and overlong metric feet. However, the prosodic difference between them is not neutralized: the syllabic ratio remains intact. It seems justified to say that in a hierarchy of prosodic cues to quantity, the ratio between syllables ranks higher than absolute duration.

Table 5. Average Durations of Syllables in Metric Feet in Long (Q2) and Overlong (Q3) Quantities, Expressed as Percentage of Total Metric Foot Duration

	Q2			Q3		
Speaker	S1	S2	S1/S2	S1	S2	S1/S2
1	48.8	51.2	0.953	65.8	34.2	1.924
2	48.3	51.7	0.934	65.5	34.5	1.899
3	48.7	51.3	0.949	63.6	36.4	1.747
4	49.0	51.0	0.961	62.0	38.0	1.632
5	48.4	51.6	0.938	66.0	34.0	1.941
Average 1-5	48.6	51.4	0.946	64.6	35.4	1.825

Note: S1 = first syllable, S2 = second syllable, S1/S2 = ratio of syllable durations.

As a control, long and overlong metric feet were measured in a poem of free verse, "Ainult kaasa minna," by Jaan Kaplinski. The poem contains twenty-nine lines of irregular length. There is no obvious attempt to use any regular metre. Two speakers were tested—Speaker 1, who had maintained absolute durational differences in the first poem, and Speaker 4, who had the lowest z-score in the first poem, indicating highest degree of neutralization of durational differences (z-scores had been calculated to determine the statistical significance of the difference between the durations of metric feet in Q2 and Q3). The number of disyllabic feet measured included 18 words in Q2 and 41 in Q3. Table 6 gives the results [12]. As can be seen from the table, both readers now maintain a difference in the absolute durations of words in Q2 and Q3; both also show durational ratios similar to those they had used in the first poem. It may be concluded that a superimposed rhythmic pattern eliminates absolute durational differences between long and overlong metric feet without neutralizing the internal durational structure of the two metric foot types.

COMPARISON OF FINNISH AND ESTONIAN

A comparison of the Finnish and Estonian results shows quite clearly that the manifestation of the trochaeic metre differs in the two languages in ways that are related to the prosodic structure of the languages.

In both languages, stress falls on the first syllable of the word that constitutes the trochaeic foot. In Finnish, presence of stress is not associated with lengthening; this becomes obvious from the clear contrast between Short-short and Long-short metric feet on the one hand, and between Short-long and Long-long metric feet on

Table 6. Average Durations (in Milliseconds) and Quantity Distribution in Disyllabic Q2 and Q3 Words in the Free-Verse Poem "Ainult kaasa minna"[a]

	Q2				Q3			
Speaker	MF	S1	S2	Ratio	MF	S1	S2	Ratio
1	370	139	231	0.602	491	334	157	2.127
4	309	128	181	0.707	430	263	167	1.575
Percentage of syllable duration of metric foot duration								
1		37.6	62.4			68.0	32.0	
4		41.4	58.6			61.2	38.8	

[a]Produced by two speakers.

Note: MF = metric feet; S1 = first syllable; S2 = second syllable; ratio = S1/S2 ratio.

the other hand. The duration of the metric foot is directly dependent on the contrastive quantity of the successive syllables.

The duration of trochaeic metric feet obtained in this study is directly comparable to observations made earlier, e.g., by Lehtonen [16]. A re-calculation of average durations of disyllabic words given by Lehtonen [16, pp. 127-129] gives the following values: Short-short—317 msec, Short-long—393 msec, Long-short—358 msec, and Long-long—492 msec. Note that in Lehtonen's data, too, the long unstressed syllable is not shortened in Short-long disyllabic words.

In Estonian, the trochaeic rhythm appears to have had some effect on the duration of the metric feet—in the direction of isochrony (which was lacking in Finnish). This suggests relatively greater importance of stress within the phonology of Estonian as compared to Finnish. The three-way quantity patterns are associated with words stressed on the first syllable. The duration of the second, unstressed syllable is not independently contrastive in Estonian as it is in Finnish.

Estonian metric feet in Q1 are comparable to the Finnish Short-short metric feet in overall duration. There is no metric foot type that would correspond to Finnish Short-long metric feet. The original assumption had been that Estonian Q2 and Q3 metric feet correspond to Finnish Long-short metric feet, but it turned out that the durations of Estonian Q2 and Q3 feet are more similar to Finnish Long-long metric feet, and there is no intermediate category in Estonian that would correspond to the Finnish Short-long and Long-short metric feet. It seems paradoxical that Finnish, with its binary quantity oppositions, has three durationally determinable metric foot types, while Estonian, with its ternary quantity oppositions, has only two.

The study has shown, however, that even in the case of neutralization of absolute duration, the ratio between syllable durations resisted neutralization. The importance of syllabic ratio in establishing the quantity of Estonian words has been established in earlier research [17]; evidently the ratios are maintained even under externally imposed semi-isochronous rhythm.

TROCHAEIC PATTERNS IN SWEDISH

Let us consider next the realization of the trochaeic pattern in Swedish—a language in which stressed syllables are always long, there are no durational contrasts in unstressed syllables either, but disyllabic words carry contrastive tonal movements. The materials recorded for this part of the study consist of the poem "Bonden Paavo" by the Finnish national poet Runeberg.[5] Five speakers were recorded in Stockholm, producing this poem and a full complement of other materials not discussed here. The poem was selected because of its direct

[5] The Swedish materials were recorded in Stockholm, Sweden, in June 1989.

comparability with Finnish trochaeic verse. The question of interest was the possible interaction between word tone and metric foot duration.

The poem consists of sixty-one five-foot lines, for a total of 305 trochaeic metric feet. The five speakers produced a total of 1525 metric feet. There were 113 metric feet (disyllabic words) carrying Accent 2; the other metric feet were treated as carrying accent 1. Metric feet that contained a pause were excluded from averages, but the final foot of one line and the initial foot of the next line were included in cases in which a line followed the other without a pause between them. Averages for the final feet were also calculated separately. The results are presented in Tables 7 and 8.

Table 7 contains average durations of metric feet (produced without internal pause) with Accent 1 and Accent 2. As may be seen from the table, four of the five speakers produced the Accent 2 words with greater average duration in medial position, but all speakers had greater length in Accent 1 metric feet in final position. Due to the relatively large standard deviations (not reported here in detail, but ranging from 53.4 for Accent 1 for Speaker 5 in final position to 150.2 for Speaker 4 in medial position, and from 61.7 for Accent 2 for Speaker 5 in final position to 130.4 for Speaker 4 in medial position), the differences between the average durations of metric feet under the two accents are not significant.

The general expectation was that metric feet bearing Accent 1 would be longer than those bearing Accent 2 (see [18]). The durational difference between the two accent types being reduced or eliminated due to the trochaeic rhythm, the question arose whether fundamental frequency patterns would likewise be neutralized, or whether the F_0 differences would be maintained. (Recall that in the Estonian case, durational differences between metric feet in quantities 2 and 3 were neutralized, but the ratio between syllable durations remained intact.) The syllable nuclei of all metric feet were measured; the measurements included duration of the syllable

Table 7. Average Durations, in Milliseconds, of Metric Feet in the Poem "Bonden Paavo"[a]

	Medial Position		Final Position	
Speaker	Accent 1	Accent 2	Accent 1	Accent 2
1	448	433	511	450
2	426	446	486	489
3	487	501	504	500
4	528	542	545	537
5	488	510	576	566
Average 1-5	475	486	524	509

[a]Produced by five speakers of Stockholm Swedish.

Table 8. Duration of Syllable Nuclei and Associated Fundamental Frequency Values in Accent 1 and Accent 2 Words in the Poem "Bonden Paavo"[a]

	First Syllable					Second Syllable				
Speaker	SN dur.	Peak at	F_0 Beg.	Peak	End	SN dur.	Peak at	F_0 Beg.	Peak	End
ACCENT 1										
1	127	66	134	148	144	70	5	144	145	137
2	118	53	120	126	125	57	10	129	129	125
3	136	50	210	220	207	67	12	210	212	206
4	148	57	177	194	179	71	4	157	157	151
5	129	47	120	126	115	72	6	115	116	111
Average	131	54	152	163	154	68	7	151	152	146
ACCENT 2										
1	120	4	149	150	123	77	12	143	146	137
2	121	3	136	137	117	73	16	126	127	122
3	136	6	225	224	173	85	22	211	220	208
4	141	8	176	177	142	87	20	174	178	165
5	124	8	117	118	96	82	19	112	115	113
Average	129	6	161	161	130	80	18	153	157	149

[a]Produced by five speakers of Stockholm Swedish.

Note: SN = syllable nucleus duration (in milliseconds); "Peak at" = location of the F_0 peak measured from the onset of the syllable nucleus; F_0 Beg., Peak, and End = fundamental frequency values (in Hz) at the beginning, peak and termination of the syllable nucleus.

nucleus, F_0 at the beginning, peak, and termination of the syllable nucleus, and the position of the F_0 peak. Table 8 presents the results of these measurements.

The speakers included three men, one relatively low-pitched woman, and one relatively high-pitched woman. Since all five speakers have been averaged together, the overall averages do not represent any particular speaker; but since the patterns were the same for all speakers, the averages may be used for generalization. The data show that a distinction between the two accents is maintained. Accent 1 is characterized by a relatively low F_0 onset frequency in the first syllable, followed by a peak at approximately 40 percent of the duration of the syllable nucleus. The peak is followed by a gradual fall of the F_0 curve from the peak in the first syllable to the end of the second syllable. The F_0 value at the end of the second syllable is only slightly lower than the onset of the first syllable.

In Accent 2, the F_0 curve starts at a relatively high frequency in the first syllable, followed by a steep fall to the end of the first syllable. The second syllable starts high, with a peak at approximately 20 percent of the duration of the syllable

nucleus. The peak is followed by a gradual fall to approximately the same level that occurred at the termination of metric feet under Accent 1.

One of the conclusions tentatively drawn from these data is that trochaeic rhythm does impose a certain amount of isochrony on the spoken text, eliminating the expected greater duration assumed to be associated with Accent 1; but this greater duration probably does not constitute a necessary identificational characteristic of the accent. F_0 differences were preserved under conditions that caused durational neutralization.

TROCHAEIC PATTERNS IN LITHUANIAN

It is interesting to compare the Swedish findings with those for Lithuanian, both being tone languages. The Swedish analysis had shown that while the fundamental frequency contrast between the two accents was maintained, the durational difference between them was not. (It is generally agreed that the tonal difference is contrastive, and the durational difference merely concomitant.) The situation is quite different in Lithuanian [4].

The Lithuanian materials analyzed for the study consisted of recordings of a four-stanza trochaeic poem and a six-stanza trochaeic poem, "Peizažas" by Jonas Aistis and "Našlaite" by Salomeja Neris.[6] The poem "Peizažas" alternates lines with four complete trochaeic feet with lines consisting of three disyllabic and a final monosyllabic foot; the poem "Našlaite" has six stanzas consisting of four lines containing four trochaeic feet each. The total for the two poems is 40 lines with 160 metric feet, of which 8 line-final feet were monosyllabic. Six speakers recorded the Lithuanian materials; thus the total number of metric feet analyzed was 960. Accent markings were provided by Dr. Antanas Pakerys after the recordings had been completed.

Traditional descriptions of Lithuanian accents [9] state that the domain of pitch accent is the accented syllable nucleus; each word contains one accent, which may occur on any syllable of the word. Accented syllables can be short or long; long accented syllables carry contrastive tone, which are referred to by the terms "acute" and "circumflex." These terms derive from labels used to describe reconstructed Indo-European tones; the phonetic realization of the Indo-European acute in Lithuanian is falling, and the realization of Indo-European circumflex is a rising tone.

Measurements made from the Lithuanian recordings include the following. In the poem "Peizažas," the duration of metric feet was measured, as well as the duration of the lines and the pauses at the end of the lines. Syllable nucleus durations were measured in both poems, as well as the F_0 profile of the accented

[6] The Lithuanian recordings were carried out in Vilnius, Lithuania, in February 1989, at the Institute of the Deaf.

syllable nucleus. The F_o profile includes the fundamental frequency values at the beginning, peak, and end of the syllable nucleus, and the position of the F_o peak. The duration of metric feet containing internal pauses was not included in the calculations of average metric foot durations.

There were six types of metric feet. Since Lithuanian words are frequently longer than two syllables, and there is only one accent per word, metric feet consisting of two unaccented syllables are possible; there were 43 such feet in the corpus, symbolized SS. 128 metric feet started with a long syllable bearing the circumflex accent (S̃S), 81 with a long syllable bearing the acute accent (Ś S), 45 with an accented short first syllable (S̀S), and 44 monosyllabic metric feet (in 4 cases, the duration of the final monosyllabic foot could not be confidently established). The materials contained 12 instances of metric feet in which both syllables were accented; these metric feet contained a word boundary, but no pause (S + S). Table 9 presents the average durations of the six types of metric feet, produced by six speakers. (The table is adapted from [4], where standard deviations are also given.)

Several observations may be made from those data. There is a gradual increase in the duration of the metric foot from stressed final monosyllabic to unstressed disyllabic, disyllabic with a short stressed syllable, disyllabic with a long syllable carrying the acute accent, disyllabic bearing the circumflex accent on the long first syllable, and metric foot consisting of two accented syllables. The duration of these (S+S) metric feet was more than twice the duration of accented monosyllabic metric feet in final position.

There appears to be no categorical difference between the durations of metric feet starting with a long syllable (bearing the circumflex or the acute accent) and metric feet starting with a short stressed syllable. The difference between S̃S and Ś S averages to 47 msec (616-569 = 47), and the difference between Ś S and S̀S equals 51 msec (569-518 = 51), both differences being smaller than one standard deviation. The influence of the presence of accent, however, is clearly indicated by the difference between the average durations of unstressed metric feet and all three types of accent-bearing feet.

Pakerys [9] had found that long vowels with the falling (acute) accent are about 1.7 times and those with the rising (circumflex) accent, slightly more than 2 times

Table 9. Average Durations, in Milliseconds, of Metric Feet in the Poem "Peizažas"[a]

Metric foot type	SS	S̃S	Ś S	S̀S	S + S	S̃
N	43	128	81	45	12	44
$\bar{x}$	426	616	569	518	715	311

[a]Produced by six speakers.
Note: N = number of occurrences.

longer than the corresponding short vowels. These ratios do not hold at the metric foot level; in the present study, metric feet with an acute accent were only 1.1 times longer, and metric feet with a circumflex accent only 1.2 times longer than metric feet with a short stressed first syllable. It appears from these data that a temporal leveling process is at work when syllable nuclei occur in metric feet that are constituents of a poetic line.

This temporal leveling process shows a tendency toward isochrony, and suggests the possibility of mutual compensation between metric feet within a poetic line. The durations of lines and pauses following them were measured in the poem "Peizažas"; the results are presented in Table 10 (based on [4]). As may be recalled, the poem consists of alternating 8-syllable and 7-syllable lines.

As becomes evident from studying the table, there is considerable variability between the speakers, but all of them present the same pattern: 8-syllable lines are longer than 7-syllable lines, and pauses following 8-syllable lines are shorter than those following 7-syllable lines. For one of the speakers—Speaker 3—temporal compensation appears almost complete: on an average, the durations of line + pause for 8-syllable lines (2414 + 661 = 3075) and for 7-syllable lines (1843 + 1154 = 2997) are equal (with a difference of less than one standard deviation).

The temporal compensation between line duration and pause duration in 8-syllable and 7-syllable lines suggests that there exists a higher-level rhythmic pattern within which the onsets of successive lines are produced at approximately equal intervals. In other words—while the individual metric feet are not strictly isochronous—a tendency toward isochrony appears to operate at the level of the next highest rhythmic unit.

The question might be raised whether the pauses represent "silent" metric feet. One might hypothesize, for example, that the pause after the 8-syllable line corresponds to one "silent" foot, and that the pause after the 7-syllable line fills in

Table 10. Average Durations of Lines and Pauses Between Lines of Productions of the Poem "Peizažas"[a]

	Durations of		Duration of pauses after	
Speaker	8-syll. lines	7-syll. lines	8-syll. lines	7-syll. lines
1	3518	2550	623	915
2	3264	2726	756	1391
3	2414	1843	661	1154
4	2676	1773	686	1156
5	2355	1838	613	1016
6	2268	1728	523	1193
Average 1-6	2749	2076	644	1138

[a]Produced by six speakers.

Note: Eight-syllable lines and seven-syllable lines are averaged separately. Durations in milliseconds.

the missing duration of the monosyllabic final foot and adds the duration of the "silent" foot, so that the sum of final monosyllabic foot and the pause after 7-syllable lines would equal two metric feet. It is true that the pause after 8-syllable lines (644 msec) is comparable to the duration of an accented disyllabic metric foot in the poem (605 msec). The duration of monosyllabic foot + pause after 7-syllable lines is 311 + 1138 = 1449 msec, which is somewhat greater than twice the duration of the average stressed disyllabic foot. Still, the tendency is there, and it is possible that a larger corpus would reduce the variability observed in the present set of data.

The presence of contrastive tone on the long first syllable of the metric foot was reflected, to a certain extent, in the duration of the metric foot. Recall that this kind of difference was not found in the Swedish materials—the (noncontrastive) durational differences between the two Swedish accents were leveled, while the F_0 contours remained distinct. The situation in Lithuanian is considerably different.

To establish the prosodic profile of the syllable nuclei, I measured the F_0 values at the beginning and end of the syllable nucleus and at the peak of the F_0 curve within the syllable nucleus in both poems. I established also the location of the peak, and calculated its position in terms of percentage of the duration of the respective syllable nucleus. Using percentages makes it possible to compare syllable nuclei of different duration; speakers differed among themselves with respect to speaking tempo.

The results are presented in the following table (Table 11) [4]. Initial position and medial position are treated separately.

A first observation of the F_0 curves on the syllable nucleus carrying the contrastive accent indicates that speakers differ among themselves with regard to the position of the F_0 peak and type of F_0 movement. On the basis of phonological descriptions according to which rising accents should have a peak on the second mora and falling accents on the first mora, one would expect one of the peaks to occur at approximately 33 percent of the duration of the syllable nucleus, and the other peak at approximately 66 percent of the syllable nucleus, with a distinct separation of the two distributions. This was clearly not the case in the data presented here. In initial position, Speaker 1 has no difference at all between the two accents; Speaker 2 shows the pattern that one might expect on the basis of traditional descriptions. The other four speakers are somewhere in between, but all of them show a later occurrence of F_0 peak in words with rising accents.

In medial position (second and third metric feet in a four-foot line), however, Speaker 2 now has later peaks in falling syllable nuclei. Speakers 3 and 4 show complete neutralization; Speakers 1, 5 and 6 show a weak tendency toward later F_0 peaks in rising syllable nuclei. (Remember that Speaker 1 had had complete neutralization in initial position.)

In overall averages, F_0 peaks in falling accents do occur somewhat earlier than F_0 peaks in rising accents, but the differences do not appear systematic enough to carry the burden of distinguishing between the two accents. Neither did the

Table 11. Prosodic Profile of Accented First Syllables of Unbroken Metric Feet in Two Lithuanian Poems[a]

Initial Position ~ —							— ' —					
Speaker	SN dur.	F_0 pk. at	%	F_0 value at Beg.	Peak	End	SN dur.	F_0 pk. at	%	F_0 value at Beg.	Peak	End
1	267	133	49.8	184	255	220	217	108	49.8	191	232	218
2	231	133	57.6	121	154	142	217	58	26.8	120	149	137
3	218	122	56.0	91	104	95	181	72	39.8	99	116	99
4	237	123	51.9	95	120	112	218	99	45.4	107	130	126
5	217	152	70.0	204	244	234	163	103	63.2	229	270	252
6	217	122	56.2	173	221	210	151	65	43.0	196	242	235
1-6	231	131	56.7	145	183	169	191	84	44.0	157	190	178
Medial Position												
1	252	136	54.0	180	221	210	283	139	49.1	174	224	202
2	272	150	55.1	102	126	121	266	160	60.2	104	126	118
3	213	102	47.9	94	105	98	213	103	48.4	94	115	100
4	216	103	47.7	98	115	107	198	95	48.0	97	118	109
5	197	110	55.8	210	235	223	216	116	53.7	207	226	213
6	213	97	45.5	192	230	218	171	65	38.0	182	193	184
1-6	227	116	51.1	146	172	163	225	113	50.2	143	167	154

[a]Produced by six speakers.

Note: Syllable nucleus durations in milliseconds; fundamental frequency values in Hz. Data for circumflex and acute accents are presented separately for initial and medial position.

measurements of the duration of syllable nuclei exhibit sufficiently great regularity to assign them unambiguously to an accent type.

To summarize, the presence of stress lengthens the metric foot by approximately 100 msec; this is the difference between 426 msec for a metric foot with two unstressed syllables and 518 msec for a metric foot with a short accented first syllable. The increment due to placement of the acute (falling) accent on the first syllable is about 50 msec, and the increment due to placing the circumflex (rising) accent on the first syllable is an additional 50 msec. The presence of a word boundary (but no pause) between two accented syllables contributes another 100 msec to the duration of the foot.

Since neither the fundamental frequency pattern by itself, nor the durational characteristics of the accented syllables, carry a clear distinction between the three contrastive accents, it will be necessary to look elsewhere for the distinctive phonetic cues. Pakerys (1986) suggested that these might be found in the interaction of vowel quality, duration, F_0 profile, and possibly intensity. Further research is clearly called for, including research into the functional load carried by contrastive accents in Lithuanian. (I have a suspicion that it is not as great as in the case of Swedish accents.)

The only clear pattern that emerged from the analysis is the relationship between the durations of spoken lines and the pauses that follow them. I interpret this as evidence for a higher-level timing pattern—rhythm based on the onset of poetic lines.

STRESS-TIMING WITHIN A POETIC LINE

The Lithuanian results indicate clearly that in the type of materials analyzed, the poetic line constituted a unit of timing. It should be added that these lines occurred in regular stanzas, so that a parallel may be drawn between the temporal compensation among metric feet within the line and between lines and following pauses within a stanza. The role of pauses is not as clearly discernible in other instances.

A curious result emerged in the case of Swedish productions of the poem discussed here, "Bonden Paavo." This poem imitates Finnish Kalevala style, and there is no stanza structure. But the pauses at the end of the lines appeared to be closely correlated with punctuation marks! The next table (Table 12) shows the average duration of pauses at the end of the lines, measured for two of the speakers. (I stopped calculating averages after the second speaker; the readers appeared to be too literate.) It may be, however, that the selection of punctuation marks corresponds to the demands of the syntactic structure and the paragraph structure of the story, and that the pauses are primary, the selection of the punctuation marks is secondary. Punctuation marks were invented, after all, to signify the presence and type of boundaries between linguistic entities.

Table 12. Average Duration, in Milliseconds, of Pauses at the End of Lines Ending with Four Types of Punctuation Marks

Speaker	Comma N = 21	Colon N = 8	Semicolon N = 11	Period N = 18
1	480	584	608	1609
2	481	605	603	1236

Note: N = number of occurrences.

Here the pauses are clearly not used to provide for isochronous onset of successive lines. It is at least possible that this characterizes poems that do not consist of stanzas—i.e., that lack this unit in the hierarchy of levels.

These Swedish lines consisted of five trochaeic metric feet. A certain degree of isochrony is preordained in such lines. Poetic lines with a fixed number of stresses occurred in various Germanic languages at an earlier age; stress-timing in such languages would require equalization of the duration of timespans between stresses. I carried out a study of stress-timing in Icelandic, using contemporary readings of an Old Icelandic poem [5].

The material consists of the first 14 stanzas of the Eddic poem *Hávamál*, recorded by five speakers in Reykjavík in July 1988.[7] The metre of the Hávamál is the *ljóðahattr*. A regular stanza has two lines; two stanzas form a strophe. The first two lines of the stanza constitute an alliterating pair, somewhat like the long line of the *fornyrðislag*; the third line (called the "full line") has its own alliteration. Each half of the long line has two metrical stresses; the two halves are bound together by alliteration of words bearing metrical stress. An ictus (stressed syllable) and following material is called a metrical foot or a measure. The "following material" consists normally of unstressed syllables; words that are full-fledged lexical items, with their own word stress, may likewise occur in non-ictus position within a metrical foot. In the materials analyzed, the number of syllables in a metric foot ranged from one to five.

There are seven positions in the long line: optional upbeat ("upbeat" refers to the material preceding a metrical stress), first foot, second foot, caesura or optional pause, optional upbeat, third foot, and fourth foot. The text consists of 29 long lines and 30 full lines. Table 13 presents average durations of components of the long line, presented separately for the five speakers.

The averages presented in this table make some generalizations possible. The upbeats are generally shorter than full metric feet. The average durations of metric

[7] The Icelandic recordings were made in July 1988 at the Reykjavík Radio Station with the help of Dr. Eiríkur Rögnvaldsson.

Table 13. Average Duration, in Milliseconds, of Components of the Long Line

Speaker	Upbeat	1.foot	2.foot	Pause	Upbeat	3.foot	4.foot
1	217	448	440	211	320	433	401
2	201	470	415	584	294	423	406
3	186	489	440	329	324	451	465
4	218	514	458	133	383	467	434
5	125	400	444	252	274	400	391
1-5	189	464	439	302	319	435	419

feet are similar in all positions. The pauses between the two halves of the long line show the greatest amount of variation between the speakers.

The table does not give information about the variability in the durations of metric feet (for details, see [5]). If we are dealing with a stress-timed language, one would expect the metric feet to approximate the same duration. This is only true when all metric feet in a given position are averaged together, as presented in Table 13. A different picture emerges, when the metric feet are tabulated according to the number of constituent syllables. Table 14 gives a breakdown of upbeat and metric foot durations according to number of syllables.

Table 14 shows clearly that metric feet are not isochronous, and that their duration increases systematically with the addition of further syllables. Upbeats remain shorter than full metric feet with the same number of syllables; this difference may be attributable to the presence of metrical stress on full metric feet.

The variability of the durations of metric feet of a given number of syllables is likewise considerably smaller than that of metric feet grouped according to positions in the line [5]. When metric feet were grouped according to number of syllables, the average standard deviation was 98.5; when metric feet were grouped by position, the average standard deviation was 120.4. The average standard deviation for pauses within the long line was about twice as large—198.8. No statistical significance is claimed for these differences; the material was not controlled tightly enough to make statistical analysis meaningful. The figures are presented simply as illustrations.

A potential role for the pause within the long line would be to provide some flexibility in arriving at lines of approximately equal duration. (This had been the case with pauses following lines in the Lithuanian trochaeic poems.) The pause could be omitted, shortened or lengthened to compensate for variable durations of the metric feet. If temporal compensation is present within the line (between

Table 14. Average Durations, in Milliseconds, of Upbeats and Full Metric Feet, Arranged According to Number of Syllables

No. of Syllables	Upbeats					Metric Feet				
	1	2	3	4	5	1	2	3	4	5
Sp. 1										
N	19	21	3	7		39	120	28	9	1
$\bar{X}$	152	236	488	578		343	439	550	625	788
Sp. 2										
N	16	19	4	9	1	39	117	20	7	1
$\bar{X}$	130	237	349	542	752	346	440	579	579	715
Sp. 3										
N	17	22	2	4	1	37	114	24	8	1
$\bar{X}$	158	285	541	581	591	346	461	628	694	774
Sp. 4										
N	17	23	4	7		40	116	23	7	2
$\bar{X}$	160	290	487	588		366	463	632	809	931
Sp. 5										
N	16	21	6	8	1	37	115	22	6	2
$\bar{X}$	123	223	402	462	526	338	388	516	561	654
1-5										
$\bar{X}$	145	254	453	550	623	348	438	581	654	772

Note: N = number of measured occurrences.

components of the line), the variance of the durations of the lines should be smaller than the sum of variances of the component parts. If there is no temporal compensation within the line, the sum of the variances of the components should equal the variance of the line. The calculations that were carried out gave ambivalent results. For three subjects, there was clearly some compensation present; for two subjects, there was some effect, but that effect appeared too small to be significant.

These results were somewhat unexpected. Germanic languages are generally assumed to be stress-timed, and the Germanic long line is cited as an example in which the original pattern is optimally manifested [19]. I asked myself whether this could be due to changes that have occurred in Icelandic on the way from the stage at which the Hávamál was composed, that is, Old Norse, to contemporary Icelandic. It might be that in the earliest stage the metric feet

were in fact isochronous, and that the changes that have occurred in the language since that time have resulted in bringing about a change in the original pattern.

The prosodic changes that have occurred in Icelandic are comparable to those that have taken place in other Germanic languages—e.g., Swedish or English: contrastive vowel duration was replaced by a system of qualitative contrasts, and length and stress became mutually defining, so that a long syllable is usually perceived as stressed, and a stressed syllable is longer than a comparable unstressed syllable. In my opinion, this change should result in introducing stress timing into a language rather than eliminating it. It appears unlikely to me that the contemporary production of metric feet in this Germanic pattern is any less isochronous than was the case at the earlier stage. (And it just might be that experimental phonetics can provide a window through which the prosodic structure of earlier stages of a language can be examined.)

SUMMARY AND CONCLUSIONS

We read in the literature a statement that a poem is written in the trochaeic metre, and we assume that we know what this implies in terms of oral production. I believe to have shown conclusively that the trochaeic metre is realized in different ways in different languages, and that the manner of its realization depends on the prosodic structure of the language. It cannot be assumed that statements made about poetic metre based on only one language are universal and it is necessary to define concepts in such a way that the concepts can be subjected to empirical verification.

There is a hierarchical structure to metrics that is comparable to a phonological hierarchy: syllables enter into metric feet, metric feet constitute poetic lines, lines may or may not be arranged into stanzas. A rough parallel might be the hierarchy of syllable—phonological word—sentence—paragraph. There are parallels between stanzas and paragraphs that I have not discussed here; certain phonetic characteristics are shared by both, such as greater pauses following them and greater degree of preboundary lengthening, compared to poetic lines on the one hand and sentences on the other. This hierarchy may be modified for particular languages—or for poetic purposes. In mora-counting or syllable-counting languages, metres may be preferred that exclude the use of feet; the haiku form in Japanese is an example, or the *deseterac* in Serbocroatian, the ten-syllable line of the Serbian epic songs. The preferred metric structure of traditional poetry is intimately connected with the prosody of the language in which the poetry is created. It is surely no accident that the Old Germanic languages used the Germanic long line with four stresses; that the Serbocroatian epic songs were transmitted in a syllable-counting metre; and that there are eight syllables in a Finnish Kalevala line.

There are, however, many questions which remain as elusive as ever. I do not know the difference between word stress and verse ictus, except for the fact that in many metres the two need not coincide, and in a Finnish Kalevala verse, a short stressed first syllable of a word must *not* occur in ictus position. At least at the stage when the Kalevala songs were created, the language users must have been aware of the difference between word stress and verse ictus. Word-initial stress is rigidly enforced in Finnish, and the studies reported here show that presence or absence of word stress on a syllable has no effect on its duration. There is no one-to-one correspondence between any acoustic parameter and perceived stress, as there is between fundamental frequency and perceived pitch. In some work not reported here, I have tried to approach the problem of how to distinguish between poetic lines composed in iambic metre and trochaeic lines with anacrusis, but I have not been able to solve the problem in a satisfactory way. My tentative suggestion is that true iambic metre is only possible in languages with free stress, so that one can have iambic feet that do not contain a word boundary. But this is a problem that remains to be solved.

One thing seems certain: the same metrical structures are realized in different ways in languages with differing prosodic structure. Theory has to be checked against experiment; if experiment is not available or possible—then theory has to be checked against the best possible observations. Metrical theory needs to take into account the phonetics of metrics.

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