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Fitting the Distribution of the Syllabic Types in Different Positions of Verse

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Abstract. The article is devoted to the study of distribution of syllabic types in three long poems by A. Pushkin, one of the founders of Russian literature. Contrary to the usually practised "linear" approach, where syllabic types are viewed as a consistent sequence in which the position of every syllabic type in a poetic line is not taken into account, the present research is focused on the "vertical" arrangement of syllables in poetic texts. In this case, the sequence under study includes syllables which occur in the same position in different lines of a poem. To reveal the peculiarities of such distributions, the Zipf-Alekseev function, which gives a good fit, and repeat rate indicator are used.

Keywords: Zipf-Alekseev function, repeat rate indicator, syllabic types, distribution, long poems.

The study of sequences of different types of syllables in poetry has demonstrated an evident order in their distribution, proving that the distribution of frequencies of syllabic types in the text is not random (Zörnig, et al. 2019).

Such research of regularities in the distribution of syllabic types has been mainly focused on the "horizontal" arrangement of syllables. This means that types of syllables were counted from the beginning of the poem to its end; the researcher successively moves from line to line without paying attention to the metric positions in these lines. In other words, all verse lines are viewed as a single sequence beginning with the first syllable in the poem and ending with its last syllable.

One of the most important peculiarities of poetic text (verse) is its double nature: its structure is organized not only in the linear, horizontal direction, as it is usual in prose, but also "vertically". Verse text is divided into lines, which have similar features. These features, when repeated, ensure a certain resemblance of verse lines. Among features supporting vertical relations between poetic lines – such as rhyme, poetic syntax (syntagmatic pauses, enjambments, syntactic links), assonance, etc. –, the most powerful and effective means of creating such similarity are metre and rhythm[2]. This raises the question of finding out if there is any regularity in the distribution of syllabic types in the same rhythmic positions in different lines.

For the purposes of the present investigation of 8–9 metric positions in the iambic tetrameter, we shall distinguish strong positions (ictuses), on which the stress should fall, and weak positions (metrically unstressed).

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[2] By metre, we understand a syllabic pattern of a line which is characterized by the number of syllables and regularity of stressed positions (ictuses), whereas rhythm is a concrete realization of metre in a line with possible deviations from its metric scheme.

The database includes 3 long poems by A. Pushkin: *Graf Nulin* ("Earl Nulin"), *Ruslan i Lyudmila* ("Ruslan and Ludmila"), *Mednij Vsadnik* ("The Bronze Horseman"). Out of each of these poems, 200 lines were taken.

In the samples, the following 17 types of syllables were found (V – vowel, C – Consonant): V, VC, CV, VCC, CVC, CCV, VCCC, CVCC, CCVC, CCCV, CVCCC, CCVCC, CCCVC, CCCCV, CVCCCC, CCCVCC, CCCCVC.

To illustrate the horizontal and vertical distributions, the first four lines from the long poem *Graf Nulin* are taken. In the coded form, the lines can be represented as it is done in Table 1. Columns are the consecutive number of a syllable in the poetic line (its position in the line), lines of the table represent the first four poetic lines from the poem.

Table 1

Syllabic types in the positions of the first 4 lines of the long poem *Graf Nulin*

	Position in the line								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Line 1	CV	CV	CV	CV	CV	CV	CCV	CVC	
Line 2	CCV	CV	CV	CVC	CV	CVC	V	CV	CVC
Line 3	CVC	CCVC	VC	CV	CV	CVC	CV	CVC	
Line 4	CVC	CV	CV	CCV	CV	CVC	CV	CCV	CVC

The count of all the types in these four lines (horizontal dimension) gives the following frequencies (down-ranked): CV = 17, CVC = 10, CCV = 4, V, CCVC and VC = 1 each. The vertical count of the types within 9 separately taken positions brings about the following frequencies (Table 2).

Table 2

Vertical distributions of syllabic types in the first 4 poetic lines of *Graf Nulin*

	Position in the line								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
CV	1	3	3	2	4	1	2	1	0
CVC	2	0	0	1	0	3	0	2	2
CCV	1	0	0	1	0	0	1	1	0
V	0	0	0	0	0	0	1	0	0
VC	0	0	1	0	0	0	0	0	0
CCVC	0	1	0	0	0	0	0	0	0

The 9th position is observed only when the author used the feminine rhyme. In this extract, it happens twice. If one is interested to study the actual end of all the lines, they should combine the syllables in the 8th position in masculine rhymes and the 9th-position syllables in feminine rhymes. Thus, in our example, the last syllable count will give the following: CVC – 4 cases (2 in masculine lines and 2 in feminine lines).

The analysis was carried out in the following way. Firstly, the horizontal dimension was studied, and then, it was compared to the vertical one.

The distribution of frequencies is fitted by the Zipf-Alekseev function (Hřebíček, 2002):

$$f_x = f_1 x^{a+b*\ln x}, \quad (1)$$

where f_1 is the frequency of syllables in $x = 1$, a and b – parameters, x – the frequency of syllabic types.

The results of the fitting are shown in Table 3. It presents the observed frequencies of the types in different metrical positions and theoretically expected frequencies, which are calculated according to the Zipf-Alekseev function. The frequencies are down-ranked.

Table 3

Frequencies of the syllabic types in metric positions of *Graf Nulin* and fitting the Zipf-Alekseev function to the sample

Types	Observed	Expected
CV	766	766.00
CVC	542	524.40
CCV	136	194.76
CCVC	102	68.37
V	82	24.93
VC	45	9.62
CCCVC	11	3.94
CVCC	8	1.70
CCCV	8	0.77
a = 0.65, b = -1.73, R^2 = 0.984		

As seen in the table, the result of the fitting is very satisfactory (98.40 %). The same holds for two other long poems (Table 4).

Table 4

Frequencies of the syllabic types in metric positions of *Ruslan i Ludmila* and *Medniy Vsadnik* and fitting the Zipf-Alekseev function to the samples

Ruslan i Ludmila			*Medniy Vsadnik*		
Types	Observed	Expected	Types	Observed	Expected
CV	718	718.00	CV	750	750.00
CVC	571	556.23	CVC	523	506.49
CCV	148	200.02	CCV	163	209.35
CCVC	104	65.48	V	97	83.47
V	64	22.02	CCVC	78	34.60
VC	54	7.82	VC	40	15.12
CCCVC	14	2.94	CVCC	14	6.96
CVCC	12	1.17	CCCV	14	3.36

CCCV	12	0.49	CCCVC	11	1.69
CCVCC	1	0.21	CCVCC	2	0.88
CCCCV	1	0.10	CCCVCC	1	0.48
CVCCC	1	0.05	CCCCVC	1	0.27
a = 0.99, b = -1.96, R^2 = 0.986			a = 0.45, b = -1.47, R^2 = 0.992		

At the second stage of analysis, syllabic types in the same metrical position in all the lines were counted (vertical dimension). As has been mentioned above, there are 8 positions in all the lines of the analyzed long poems and an additional one – 9th position – in those lines which have feminine rhymes.

Table 5 presents the observed and theoretically expected (according to the Zipf-Alekseev function) frequencies of the syllabic types in *Graf Nulin*.

Table 5

Fitting the Zipf-Alekseev function to *Graf Nulin* (vertical dimension)

Rank	Position 1		Position 2		Position 3		Position 4	
	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp
1	69	69.00	86	86.00	112	112.00	82	82.00
2	35	41.56	83	82.80	47	44.90	72	71.02
3	31	28.02	11	12.90	14	19.63	22	25.64
4	26	20.27	8	1.52	11	9.58	12	8.19
5	21	15.38	5	0.18	8	5.09	4	2.66
6	14	12.08	4	0.02	6	2.89	3	0.91
7	3	9.74	2	0.00	1	1.74	3	0.33
8	1	8.01	1	0.00	1	1.09	1	0.13
9			1	0.00			1	0,05
	a = -0.58 b = -0.22 R^2 = 0.934		a = 2.80 b = 4.12 R^2 = 0.991		a = -0.86 b = -0.66 R^2 = 0.994		a = 1.25 b = -2.10 R^2 = 0.995	

Rank	Position 5		Position 6		Position 7		Position 8	
	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp
1	88	88.00	94	94.00	108	108.00	83	83.00
2	76	75.48	64	62.47	39	42.35	77	75.98
3	12	15.60	13	19.36	28	21.73	19	23.65
4	11	2.62	11	5.55	13	12.82	13	6.27
5	5	0.45	10	1.66	8	8.26	4	1.68
6	5	0.08	5	0.53	3	5.66	3	0.48

7	2	0.02	1	0.18	1	4.05	1	0.14
8	1	0.00	1	0.07				
9			1	0.03				
	a = 2.09 b = -3.34 R^2 = 0.985		a = 0.86 b = -2.09 R^2 = 0.982		a = -1.16 b = -0.27 R^2 = 0.992		a = 1.61 b = -2.50 R^2 = 0.990	

Rank	Position 9		All final syllables	
	Obs	Exp	Obs	Exp
1	53	53.00	104	104.00
2	44	44.00	72	71.74
3	3	3.00	14	15.66
4			6	2.97
5			4	0.58
	a = 3.74 b = -5.78 R^2 = 1.000		a = 1.49 b = -2.93 R^2 = 0.997	

The long poem *Graf Nulin* was written by Pushkin in 1825. It is possible to compare these results with the results of the similar analysis of two poems of the same author – one, written earlier, in 1818–1820 (*Ruslan i Ludmila*), and the other, written later, in 1833 (*Medniy Vsadnik*).

The results of the fitting of the Zipf-Alekseev function to the two samples are presented in Tables 6 and 7.

Table 6

Fitting the Zipf-Alekseev function to *Ruslan i Ludmila*

Position in the line	*a*	*b*	R^2
1	-0.62	-0.24	0.949
2	1.57	-2.32	0.994
3	0.84	-2.18	0.990
4	0.76	-1.46	0.988
5	1.33	-2.36	0.980
6	0.62	-1.75	0.977
7	0.24	-1.26	0.997
8	2.16	-3.34	0.987
9	5.23	-8.10	1.000
All final syllables	2.35	-4.15	0.999
Horizontal dimension	0.99	-1.96	0.986

Table 7
Fitting the Zipf-Alekseev function to *Medniy Vsadnik*

Position in the line	*a*	*b*	R^2
1	-0.08	-0.49	0.944
2	1.08	-2.21	0.987
3	0.42	-1.42	0.999
4	1.24	-2.06	0.982
5	0.19	-1.67	0.990
6	1.38	-2.29	0.981
7	-0.18	-0.91	0.995
8	2.43	-3.77	0.989
9	0.87	-3.22	0.999
All final syllables	3.29	-4.93	0.995
Horizontal dimension	0.45	-1.47	0.992

Very good results of the fitting may be recognized as rather unexpected. In verse, where there exist semantic, morphological, and syntactic links and interconnections between both words and text structures (not to speak of the rules of purely poetic restrictions), and where, on the other hand, there are numerous rules of possible deviations from the metric scheme, it was difficult to expect any order in the vertical arrangement of syllabic types, not to speak of the order which is similar to the order of their distribution in the horizontal dimension.

Since all the three poems were written in the iambic tetrameter, the stressed positions (ictuses) predominantly fall on the 2nd, the 4th, the 6th, and the 8th syllables. Comparing the syllabic types distribution in these strong positions with those observed in the unstressed positions (1st, 3rd, 5th, 7th, and 9th), we do not see any difference, except that the first position displays a little lower values of R^2. Contrary to the beginning of the line, the final syllables distribution (all final syllables) is fitted very well.

The long poems chosen for the analysis are different not only in the year of their creation, but also in the circumstances of the author's life.

Ruslan and Ludmila, one of the first literary works which made Pushkin famous, was written at his early age – he began working on it during his studies at a lyceum and finished the poem soon after the completion of his studies. This romantic poem combines the style of poetic ballads possessing heroic, tragic, and satiric themes. It was written in 1818–1820 (with additional parts in 1825 – they were not included in our sample).

Graf Nulin is a poem of a highly humorous nature with a frivolous plot and a large number of colloquial words. It is one of the first works of the author in the realistic style, and was written by Pushkin in exile during two mornings in 1825.

Medniy Vsadnik is one of the most celebrated works by Pushkin, which he wrote during a very creative period of his life in 1833. Working on the poem, Pushkin made tremendous efforts to achieve an ideal form, rewriting all its parts many times (some lines – up to ten times). The chosen sample contains emotionally elevated and lofty lexis, describing the statuesque beauty of the capital of the empire.

Thus, we see that there are very strong divergences among the texts in quite a number of aspects (genre, the age of the author, plot, time spent writing the poems, lexis, style), but the general tendencies of the distribution of syllabic types in the same positions hold good for all of them.

One more important aspect of characterizing the distribution of the elements in text consists in finding out their density. For this purpose, an indicator of repeat-rate was suggested (Altmann, Kohler, 2015; Herfindahl, 1950). It is computed as follows (Andreev, Místecký, Altmann, 2018: 96):

$$R = \sum_{i=1}^{k} p_i^2 \; ; \tag{3}$$

for p_i, we get:

$$p_i = \frac{x_i}{N}, \tag{4}$$

where k is the number of types, p is the relative frequency of the given type, x_i is the frequency of syllabic type, and N is the total number of all syllables in the same position in the vertical sequence.

It is also recommended to relativize R using the formula (Andreev, Místecký, Altmann, 2018: 97):

$$R_{rel} = \frac{1 - R}{1 - \frac{1}{N}}. \tag{5}$$

The frequencies of the types of syllables in different positions of the lines in *Graf Nulin* were given in Table 2. The calculated values of the repeat-rate indicator for the poems are presented below (Tables 8–10).

Table 8

Relativized values of the repeat-rate indicator for types of syllables in different metric positions of *Graf Nulin*

Positions	R	R_{rel}	Positions	R	R_{rel}
P1	0.207	0.797	P6	0.334	0.670
P2	0.363	0.640	P7	0.355	0.648
P3	0.379	0.624	P8	0.334	0.669
P4	0.314	0.689	P9	0.475	0.530
P5	0.346	0.657	Final (PF)	0.406	0.597

Table 9
Frequencies of types of syllables in different metric positions in *Ruslan i Ludmila* and relativized values of the repeat-rate indicator

Types	P1	P2	P3	P4	P5	P6	P7	P8	P9	PF
V	34	1	6	2	0	11	9	1	0	1
CV	72	78	99	66	86	90	92	79	56	75
CCV	26	23	14	19	16	11	25	13	1	2
CVC	32	77	63	76	71	62	60	87	43	108
CCVC	13	13	7	24	11	14	10	12	0	9
CVCC	1	2	0	1	4	2	0	2	0	0
CCCV	5	0	2	0	2	2	1	0	0	0
VC	16	2	8	5	10	7	3	3	0	3
CCVCC	0	1	0	0	0	0	0	0	0	0
CCCVC	1	3	1	5	0	1	0	3	0	2
CCCCVC	0	0	0	1	0	0	0	0	0	0
CVCCC	0	0	0	1	0	0	0	0	0	0
N	200	200	200	200	200	200	200	200	100	200
R	0.212	0.318	0.353	0.278	0.323	0.311	0.322	0.354	0.499	0.435
R_{rel}	0.792	0.685	0.650	0.725	0.680	0.692	0.681	0.650	0.507	0.568

Table 10
Frequencies of types of syllables in different metric positions in *Medniy Vsadnik* and relativized values of the repeat-rate indicator

Types	P1	P2	P3	P4	P5	P6	P7	P8	P9	PF
V	40	9	10	3	12	12	9	2	0	0
CV	62	90	91	71	109	79	95	89	64	93
CCV	34	16	25	16	12	17	30	10	3	4
CVC	31	67	62	79	57	70	53	79	25	85
CCVC	15	9	6	19	4	7	7	11	0	8
CVCC	1	0	0	3	0	4	0	4	2	6
CCCV	3	0	3	4	0	1	3	0	0	
VC	12	4	3	4	4	7	3	3	0	3
CCVCC	0	1	0	0	0	1	0	0		
CCCVCC	0	0	0	0	0	1	0	0		
CCCVC	2	3	0	1	2	1	0	2		1
CCCCVC	0	1	0	0	0	0	0	0		
N	200	200	200	200	200	200	200	200	94	200

R	0.199	0.326	0.323	0.299	0.386	0.292	0.322	0.360	0.536	0.400
R_{rel}	0.805	0.678	0.681	0.705	0.617	0.711	0.681	0.643	0.469	0.603

It is possible to study metrical positions themselves from the point of view of the peculiarities which syllabic types distributions display in them. For this purpose, both measures, the Zipf-Alekseev formula and the repeat-rate indicator, are used. In the Zipf-Alekseev formula, parameter "a" is interpreted as the feature of the language at large, whereas parameter "b" shows the changes made by the author of the text (Hřebíček, 2002). This is why for the study of the relationship of different metric positions, out of the two parameters the latter was chosen (Table 11). Graphically, this is represented in three scatterplots, in which the horizontal axis represents the values of the repeat rate indicator and the vertical axis – those of the parameter "b" (Fig. 1–3).

Table 11

Repeat-rate indicator and parameter "b" of the Zipf-Alekseev function

Position in line	*Ruslan i Ludmila*		*Graf Nulin*		*Medniy Vsadnik*	
	R_{rel}	b	R_{rel}	b	R_{rel}	b
1	0.79	-0.24	0.80	-0.22	0.81	-0.49
2	0.69	-2.32	0.64	-4.12	0.68	-2.21
3	0.65	-2.18	0.62	-0.66	0.68	-1.42
4	0.73	-1.46	0.69	-2.10	0.70	-2.06
5	0.68	-2.36	0.66	-3.34	0.62	-1.67
6	0.69	-1.75	0.67	-2.09	0.71	-2.29
7	0.68	-1.26	0.65	-0.27	0.68	-0.91
8	0.65	-3.34	0.67	-2.50	0.64	-3.77
9	0.51	-8.10	0.53	-5.78	0.47	-3.22
LF	0.57	-4.15	0.47	-2.93	0.60	-4.93

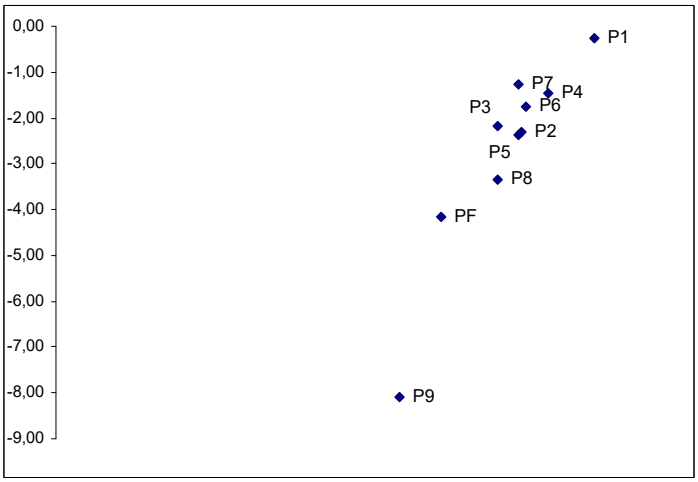

Fig. 1. Scatterplot of the metric positions in *Ruslan i Ludmila*

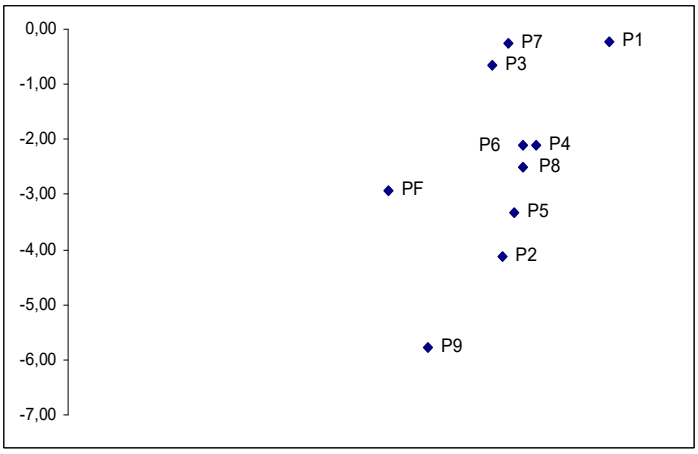

Fig. 2. Scatterplot of the metric positions in *Graf Nulin*

Fig. 3. Scatterplot of the metric positions in *Medniy Vsadnik*

As seen in the scatterplots, the earliest poem (Fig. 1) demonstrates some signs of correlation of two measures, which is less obvious in two other poems.

P1 and P9 (Fig. 1 and Fig. 2) are positioned at a long distance from each other and from the "nucleus", which consists of strong (stressed) positions P2, P4, P6, and weak (unstressed) positions P3 and P5. On the other hand, positions P8 and PF, which are forming the end of the line, are rather different in their positions in two scatterplots (Fig. 1 and 2) and to some extent in Figure 3, too.

Positions P1 and P7, which precede the first and the last ictuses in the line respectively, demonstrate similar characteristics, as seen in all three diagrams, thus forming a certain "frame" of the poetic line. One more remark refers to the general layout – in the early poem, the scatterplot is more concentrated, in the third scatterplot (the mature creative period), the points are dispersed most of all.

On the whole, the study demonstrated that the vertical distributions of syllables (vertical sequences of syllables) are ordered, and are fitted very well by the Zipf-Alekseev function. The period of creative activity and genre do not influence the distribution of syllabic types in metric positions very much.

The distribution of types of syllables in the first metric position is comparatively less fitted by the above-mentioned function, forming an opposition to most of the other positions, especially ictuses, and together with the 7th metric position creates a sort of a frame in poetic lines. Ictuses (even syllables) form the distribution nucleus of the line, whereas odd syllables are less uniform, especially in their values of repeat-rate.

The presented results are only a first step, and indicate the potential of the utilized approach to uncover syllabic types distribution in verse. Further research may include a broader investigation of long poems by various authors in different languages.

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