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Probability distribution of dependency distance

Haitao Liu, Beijing[1]

Abstract. This paper investigates probability distributions of dependency distances in six texts extracted from a Chinese dependency treebank. The fitting results reveal that the investigated distribution can be well captured by the right truncated Zeta distribution. In order to restrict the model only to natural language, two samples with randomly generated governors are investigated. One of them can be described e.g. by the Hyperpoisson distribution, the other satisfies the Zeta distribution. The paper also presents a study on sequential plot and mean dependency distance of six texts with three analyses (syntactic, and two random). Of these three analyses, syntactic analysis has a minimum (mean) dependency distance.

Keywords: Probability distribution, Dependency distance, Chinese treebank

1 Introduction

Dependency analysis of a sentence can be seen as a set of all dependencies found in the sentence (Tesnière 1959, Nivre 2006, Hudson 2007). Figure 1 displays a dependency analysis of the sentence *The student has a book*.

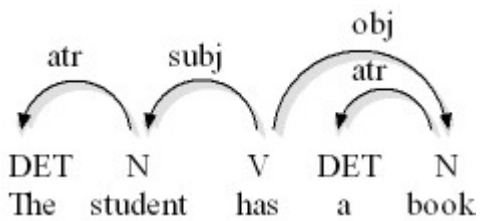

Figure1. Dependency structure of *The student has a book*

Figure 1 shows the dependency between *dependent* and *governor*, whose edges have been labeled with the *dependency type*. The directed edge from *governor* to *dependent* demonstrates the asymmetrical relation between the two units.

Treebanks are corpora with syntactic annotation. They are often used in computational linguistics as a resource for training and evaluating a syntactic parser (Abeillé, 2003). Figure 1 can be represented as shown in Table 1.

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Table 1
Annotation of *The student has a book* in a dependency treebank

Dependent			Governor			Dependency type
Order number	Character	POS	Order number	Character	POS	
1	The	det	2	student	n	atr
2	student	n	3	has	v	subj
3	has	v				
4	a	det	5	book	n	atr
5	book	n	3	has	v	obj

Dependency distance is the linear distance between governor and dependent (Hudson 1995). The concept was first used in Heringer/Strecker/Wimmer (1980:187). Formally, let $W_1 \ldots W_i \ldots W_n$ be a word string. For any dependency relation between the words W_a and W_b, a, b are order numbers of the words W_a and W_b ($1 \leq a \leq n$, $1 \leq b \leq n$, $a \neq b$); if W_a is governor and W_b is dependent, then the dependency distance (*DD*) between them can be defined as the absolute value of the difference a-b; by this measure, adjacent words have a *DD* of 1. For instance, a series of dependency distances can be obtained from the sentence in Table 1 and Figure 1 as follows: 1 1 1 2. In other words, the example has three dependencies with *DD* = 1 and one dependency with *DD* = 2. Using the same method, we can also extract a series of dependency distances from a text.

Formula (1) can also be used to calculate the mean dependency distance of a larger collection of sentences, such as a text:

$$\overline{DD} = \frac{1}{n-s} \sum_{i=1}^{n-s} | DD_i | \tag{1}$$

In this case, n is the total number of words in the text, s is the total number of sentences in the text. DD_i is the dependency distance of the i-th syntactic link of the text.

This paper will investigate the probability distribution of dependency distances of six texts, taken from a Chinese treebank. To better position the distribution found, we also compare the results with two samples of dependency treebanks with randomly generated governors.

In the next section, the frequency distribution of dependency distances based on the treebank and their fitting, using the software package *Altmann-Fitter* (1994/2005), are presented. Section 3 lists several results of dependency distance analyses of the six texts in question, but with randomly generated governors. Section 4 shows the result of a sequential plot and mean dependency distances of the texts. Section 5 presents concluding remarks and directions for further work.

2 Distributions of Dependency distances

The Chinese dependency treebank used here is based on the news (*xinwen lianbo*) of China Central Television, a genre which is intended to be spoken but whose style is similar to written language. The treebank includes 711 sentences and 17,809 word tokens; the mean sentence length is 25 words. To maintain text homogeneity, we have randomly extracted six texts from the treebank. Each reports on a relatively independent event.

Since distance can be measured in different ways, and we wish to keep the result more general, we derive the model of distance distribution in a continuous way. We start from the simple assumption that the relative rate of change of frequency ($f(x)$) is negatively proportional to the relative rate of change of distance (x), i.e.

(1) $$\frac{df(x)}{f(x)} = -\frac{a}{x}dx.$$

Solving this simple differential equation, used very frequently in linguistics, we obtain

(2) $$f(x) = \frac{K}{x^a}.$$

Since we measured the distance discretely and texts are finite, we transform (2) into a discrete distribution and compute the normalizing constant K, i.e. we set

(3) $$P_x = \frac{K}{x^a},\ x = 1, 2, ..., R$$

where R is the point of right truncation. We define the function

$$\Phi(b,c,a) = \sum_{j=1}^{\infty} \frac{b^j}{(c+j)^a}$$

and since in (3) we have $b = 1$, $c = 0$, and the greatest distance is R, we obtain by simple subtraction the result $K = [\Phi(1,0,a)-\Phi(1,R,a)]^{-1}$. Hence, finally we obtain

(4) $$P_x = \frac{1}{x^a[\Phi(1,0,a)-\Phi(1,R,a)]},\quad x = 1, 2, ..., R$$

representing the right truncated Zeta distribution (or Zipf distribution). The normalizing constant can be simply written as the sum $K^{-1} = \sum_{j=1}^{R} j^{-a}$.

We extract from the treebank six texts and calculate the frequency of dependency distance of all dependences in texts. Then we use the software *Altmann-Fitter* to fit the right truncated Zeta distribution to the observed data. The results for the six texts are shown in Table 2. Hence, the hypothesis is considered as compatible with the data.

Table 2
Fitting the right truncated Zeta distribution to the dependency distances in six texts

No.	X^2	DF	P	a	R	N
001	22.72	18	0.202	1.625	21	389
002	32.50	24	0.115	1.561	28	385
003	22.26	23	0.505	1.602	37	233
004	22.69	17	0.160	1.631	20	346
005	24.57	21	0.266	1.650	27	361
006	15.30	18	0.641	1.634	23	295

No – ordinal number of the texts; X^2 – Chi-square; *DF* – degrees of freedom; *P* – probability of Chi-square; *a, R* – parameters of the right truncated Zeta distribution; *N* – number of the word tokens in the text.

It would be preferable to list complete results for all six texts, but to save space, we only give an example from the six texts as an illustration of the program's output.

Table 3
Fitting the right truncated Zeta distribution to
the dependency distances in text 006

Distance x	Frequency	NP_x
1	143	144.50
2	43	46.57
3	29	24.01
4	6	15.01
5	17	10.43
6	7	7.74
7	7	6.02
8	4	4.84
9	5	3.99
10	5	3.36
11	4	2.88
12	3	2.50
13	1	2.19
14	1	1.94
15	1	1.73
16	2	1.56
17	2	1.41
18	1	1.29
19	2	1.18
20	2	1.08
21	0	1.00
22	1	0.97
23	1	0.86
a = 1.6335, R = 23, X^2 = 15.30, DF = 18, P = 0.64		

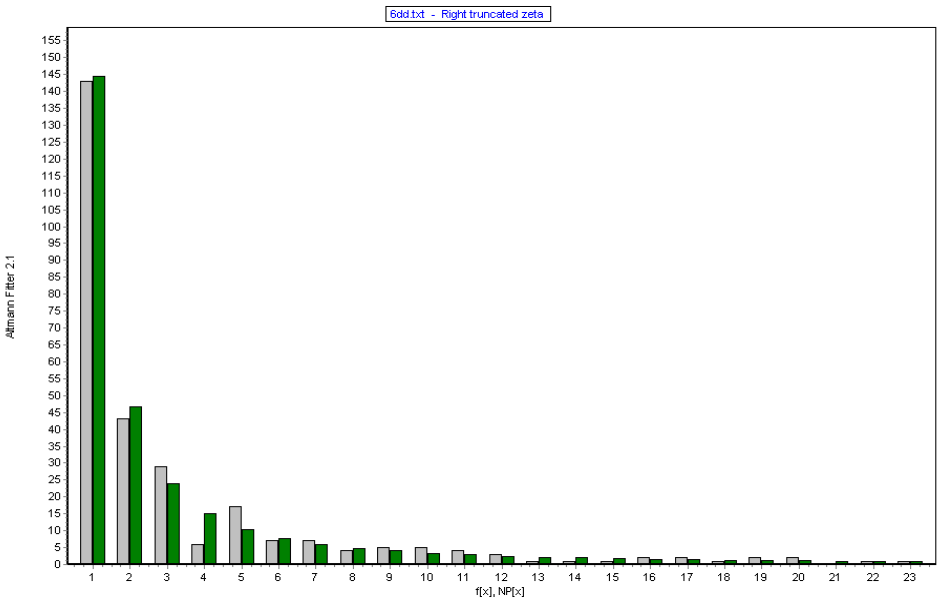

Figure 2. Fitting the right truncated Zeta distribution to the dependency distances in text 006.

3 Distribution of dependency distances in two random treebanks

Section 2 corroborates the adequateness of the right truncated Zeta distribution for the distribution of dependency distances. The following questions arise: What role does syntax play in such a distribution? If we form dependencies by randomly linking words in the same texts, would the distribution still follow the right truncated Zeta distribution? In other words, are our hypotheses in section 2 characteristic of syntactic dependency structures or is the Zeta distribution a general property of a word net?

To answer these questions we construct two randomly generated versions of a segment of the treebank for the same six texts. Ideally, we could produce a language with a randomly generated lexicon and sentences, but it is difficult or impossible to syntactically analyze such a language. Therefore, by randomly assigning the governor for all words in a dependency analysis of a text, we can build a random dependency version as a sample of a random language with dependency analysis. We use two methods to generate two random dependency samples.

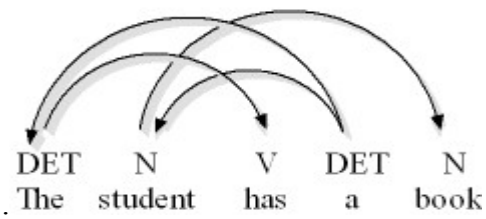

Figure 3. A possible random analysis of *The student has a book* with crossing arcs

In the first random analysis (RL1), disregarding syntax and meaning, within each sentence we select one word as root, and then, for each other word, randomly select another word in the same sentence as its governor. In this way, we can generate a possible random analysis of the sentence in Figure 3.

In the second random analysis (RL2), while the governor is assigned to a word, only dependency trees are generated which are projective and connected graphs, i.e. without crossing edges. Nivre (2006: 53) gives a formal definition of projectivity, which was first discussed by Lecerf (1964) and Hays (1964). Figure 4 is such a possible random analysis of the sentence in Figure 1.

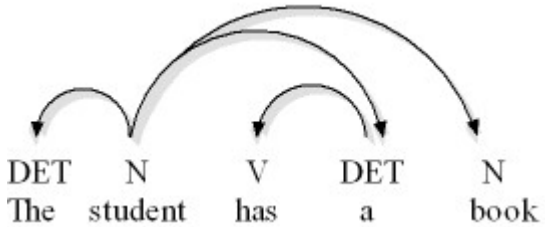

Figure 4. A possible random analysis of *The student has a book* without crossing edges

3.1 Distribution of dependency distances in random analysis RL1

After randomly assigning the governors for all words in six texts, we calculate the dependency distances of the six texts and use the *Altmann-Fitter* to find a possible empirical model, because there is as yet no theoretical assumption from which we could start. It is noteworthy that the distributions do not agree any more with the right truncated Zeta distribution, as could be expected. Instead, we found that randomly generated structures are best characterized by a different distribution: The *Altmann-Fitter* shows that the Hyperpoisson distribution, for instance, is a good model for all six texts with randomly generated governors. The Hyperpoisson distribution is defined as

$$(5) \quad P_x = \frac{a^x}{b^{(x)}\,{}_1F_1(1;b;a)}, \quad x = 0,1,2...$$

where $b^{(x)} = b(b+1)\ldots(b+x-1)$ and ${}_1F_1(.)$ is the confluent hypergeometric function. We used here the 1-displaced version without truncation at the right hand side. In Table 4, the results of fitting are presented. However, in Table 5 and Figure 5, one can see the massive irregularity of the observed data. The distribution is not even monotonously decreasing; hence another model – even displaying a greater chi-square – would be more adequate, e.g. the negative binomial capturing the bell shape at the beginning of the data. But since the negative binomial has the geometric as its special case and the Hyperpoisson converges to the geometric when $a \to \infty$, $b \to \infty$ and $a/b \to q$, we can save one parameter if we choose the geometric distribution. Even in that case, we still obtain a chi-square with $P = 0.30$

Table 4
Fitting the Hyperpoisson distribution to the dependency distances in six texts (RL1)

No.	X²	DF	P	N	a	b
001	39.99	41	0.515	52	1121.21	1204.19
002	44.31	58	0.907	75	787.60	802.59
003	38.69	39	0.484	49	705.72	741.09
004	32.48	36	0.637	44	881.37	956.53
005	26.32	37	0.904	48	367.02	368.77
006	39.28	56	0.956	56	7193.47	7612.17

Table 5
Fitting the Hyperpoisson distribution
to the dependency distances in text 002 (RL1)

X[i]	F[i]	NP[i]	X[i]	F[i]	NP[i]
1	13	15.32	39	4	3.16
2	17	15.03	40	2	2.96
3	17	14.73	41	3	2.77
4	16	14.42	42	2	2.59
5	16	14.10	43	2	2.42
6	17	13.77	44	1	2.25
7	12	13.43	45	1	2.10
8	14	13.08	46	1	1.95
9	10	12.72	47	0	1.81
10	15	12.36	48	2	1.68
11	10	12.00	49	3	1.56
12	9	11.63	50	1	1.45
13	10	11.26	51	2	1.34
14	13	10.88	52	0	1.24
15	9	10.51	53	1	1.14
16	8	10.14	54	0	1.05
17	8	9.77	55	0	0.97
18	3	9.40	56	0	0.89
19	10	9.03	57	0	0.82
20	5	8.67	58	2	0.75
21	11	8.31	59	0	0.69
22	15	7.95	60	0	0.63
23	6	7.61	61	0	0.57
24	8	7.27	62	0	0.52
25	4	6.93	63	0	0.48
26	6	6.60	64	2	0.44
27	8	6.29	65	0	0.40
28	6	5.97	66	3	0.36
29	9	5.67	67	0	0.33
30	6	5.38	68	0	0.30
31	5	5.09	69	0	0.27
32	6	4.82	70	0	0.24
33	6	4.55	71	0	0.22
34	8	4.30	72	0	0.20
35	2	4.05	73	1	0.18
36	4	3.81	74	1	0.16
37	4	3.58	75	1	1.32
38	5	3.37			

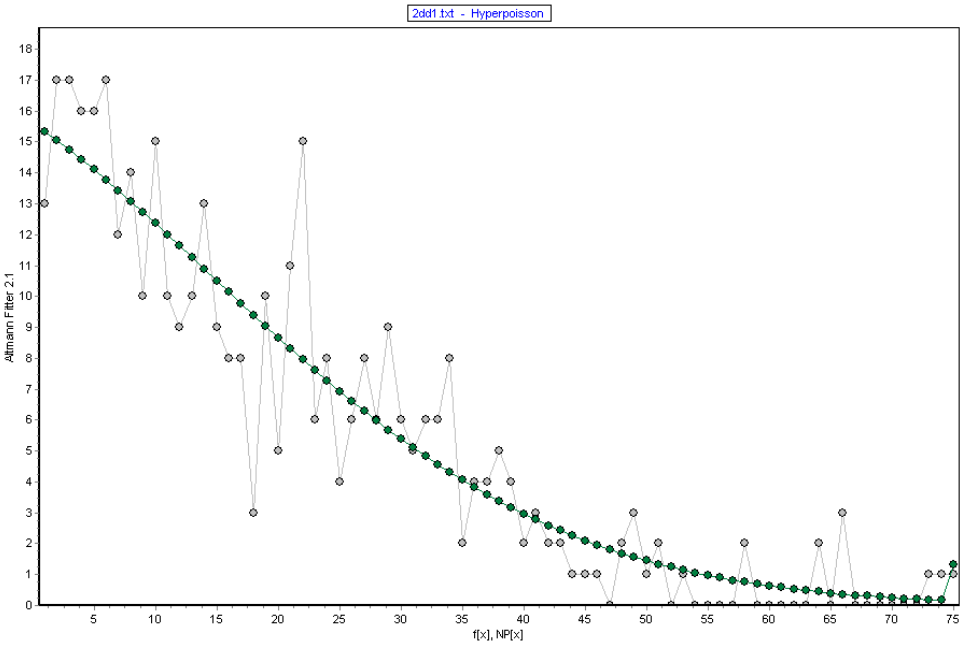

Figure 5. Fitting the Hyperpoisson distribution to the dependency distances in text 002 (RL1).

Table 4 shows that the distribution of the dependency distances of six texts with randomly generated governors abide by the Hyperpoisson distribution, but a number of other distributions would be adequate, too. However, the observed data displayed in Figure 5 do not comply with the linguistic expectation of an "honest" distribution.

3.2 Distribution of the dependency distances in random analysis RL2

Obviously, the dependency graph generated by the above-mentioned method is not syntactic. Projectivity is a feature of most dependency graphs (trees) of natural language, although there are non-projective structures in some languages. Therefore, to find the influence of projectivity on the distribution of dependency distances, we add the constraint of projectivity (no crossing edges) when generating randomly the governor of a dependency graph.

In this subsection, we present the result of fitting the right truncated Zeta to dependency distance in RL2.

Table 6
Fitting the right truncated Zeta distribution to
the dependency distances in six texts (RL2)

No.	X^2	DF	P	a	R
001	21.92	38	0.983	1.389	48
002	38.06	45	0.759	1.394	65
003	31.29	30	0.401	1.408	46
004	29.83	34	0.672	1.388	43
005	25.44	33	0.824	1.334	36
006	29.70	36	0.761	1.388	52

Table 7
Fitting the right truncated Zeta distribution
to dependency distance in text 003 (RL2)

X[i]	F[i]	NP[i]	X[i]	F[i]	NP[i]
1	84	88.36	24	0	1.01
2	36	33.31	25	2	0.95
3	32	18.82	26	1	0.90
4	17	12.55	27	1	0.85
5	7	9.17	28	1	0.81
6	6	7.09	29	0	0.77
7	1	5.71	30	1	0.74
8	3	4.73	31	1	0.70
9	3	4.01	32	0	0.67
10	3	3.46	33	0	0.64
11	4	3.02	34	0	0.62
12	2	2.67	35	0	0.59
13	3	2.39	36	0	0.57
14	2	2.15	37	0	0.55
15	2	1.95	38	0	0.58
16	3	1.78	39	0	0.51
17	0	1.68	40	0	0.49
18	2	1.51	41	0	0.47
19	0	1.40	42	0	0.46
20	1	1.30	43	1	0.44
21	2	1.22	44	1	0.43
22	1	1.14	45	1	0.42
23	0	1.07	46	1	0.40

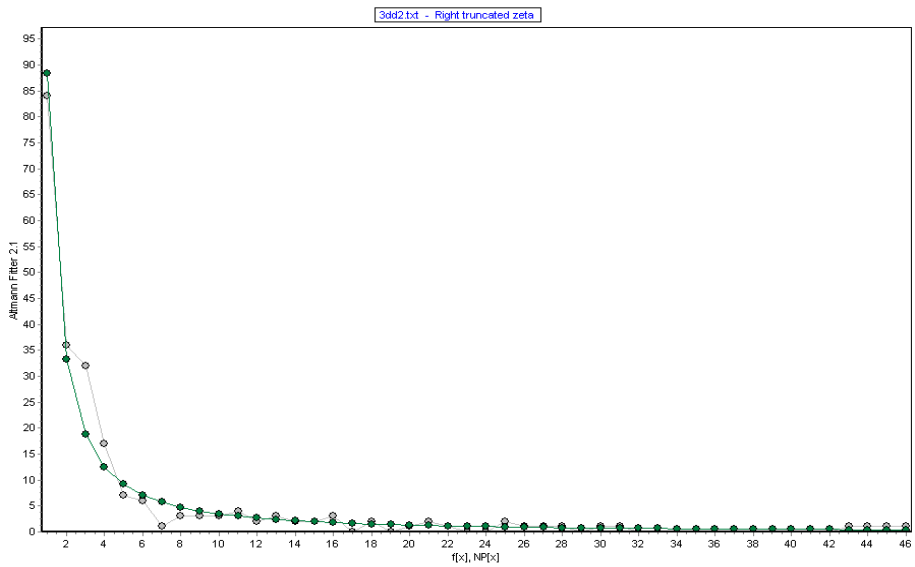

Figure 6. Fitting the right truncated Zeta distribution to dependency distance in text 003 (RL2)

It is interesting to note that the results have the same good agreement with the right truncated Zeta distribution as natural language. Evidently, projectivity is the background mechanism of this phenomenon.

4 Sequential plot and mean dependency distance

The results in section 3 show that the distribution of dependency distances may not be a sufficient or unique criterion to distinguish syntactic and non-syntactic data. Ferrer i Cancho (2006) suggests that the uncommonness of crossings in the dependency graph could be a side-effect of minimizing the Euclidean distance between syntactically related words. In other words, perhaps we have to investigate the mean dependency distance of a text in three manners (syntactic, RL1 and RL2).

To compare the distribution of dependency distances in three samples, we use sequential plots of dependency distances for text 1 in three analyses (syntactic, RL1 and RL2) as shown in Figure 7.

Figure 7 shows that dependency distance in RL1 has the greatest fluctuant range, the constraint "no-crossing edges" decreases the range in RL2, and the role of syntax is also obvious in minimizing dependency distances of a sentence or text. The comparison of pictures in Figure 7 shows that in NL (syntactic) texts there is still another mechanism (besides projectivity) rendering the sequence of distances almost homogeneous; while RL2 arising randomly has a much greater fractal dimension and the oscillation could, perhaps be captured by a very complex Fourier analysis. But no generalization is possible before other languages have been analyzed.

Using formula (1), we can obtain the mean dependency distance of six texts in three manners. The results are shown in Table 9.

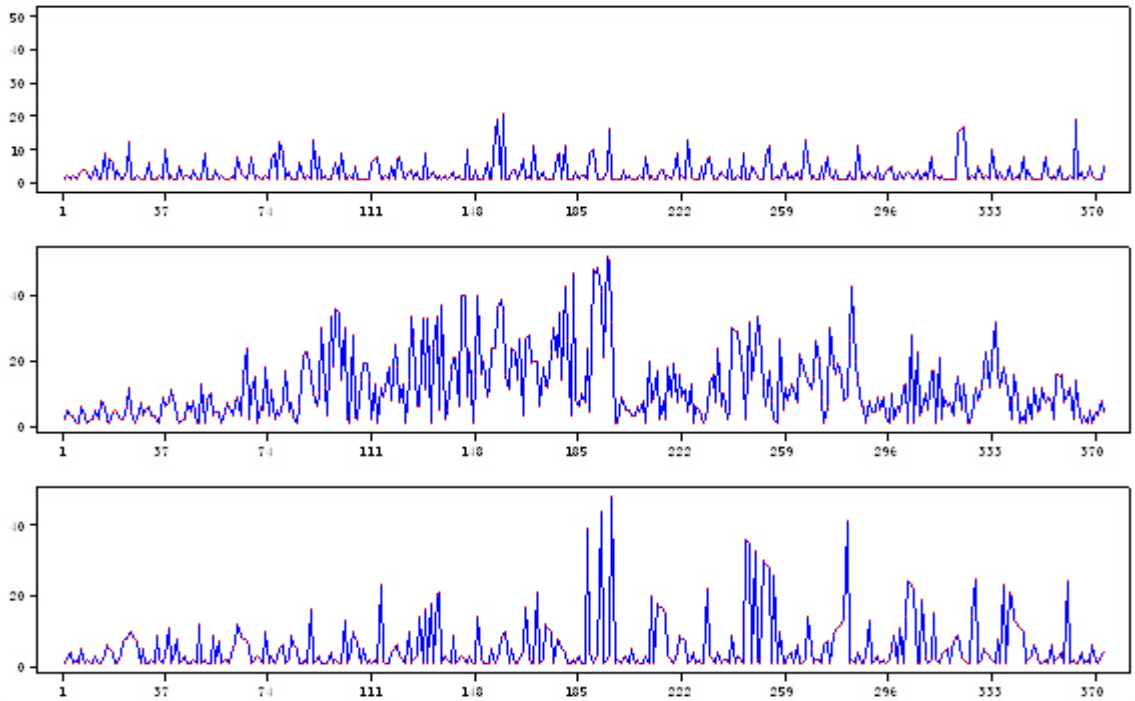

Figure 7. Sequential plots of text 001. Above: syntactic (NL); Middle: RL1; Below: RL2.

Table 9
Mean dependency distances of six texts

Text	NL	RL1	RL2
1	2.971	12.040	5.421
2	3.427	18.575	5.925
3	3.636	12.693	5.253
4	3.027	10.015	4.834
5	3.360	11.209	4.969
6	3.387	17.080	5.770
MDD	3.3	13.6	5.4

Figure 8 shows diagrammatically the change of the range and the distribution of mean dependency distances in 6 texts.

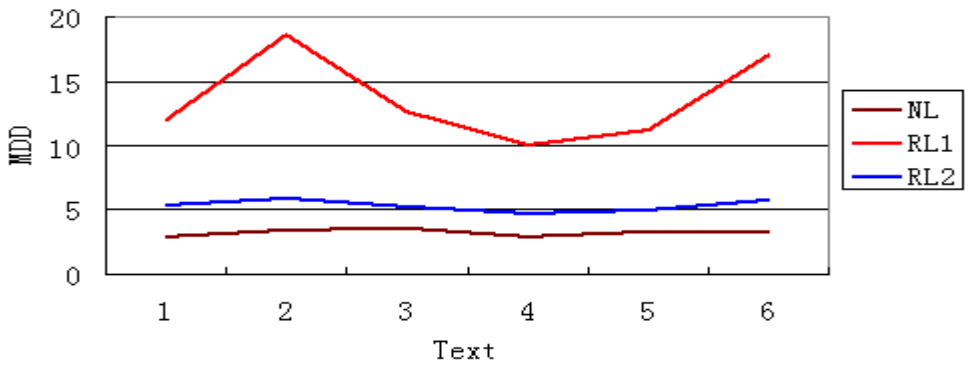

Figure 8: Distribution of mean dependency distance in NL, RL1 and RL2

Our experiments show that projectivity can restrict the dependency distances (Ferrer i Cancho 2006), because RL2 has a lower mean DD than RL1. However, it is also noteworthy that we cannot explain why natural language has a minimized mean DD from this point of view only. Figure 8 demonstrates that natural language has a smaller mean DD than RL2. That suggests that syntax also plays a certain role in minimizing the mean DD of a language. Figure 8 provides a functional view of syntactic word-order restrictions: one of their (many) benefits is the reduction of the mean DD of a sentence or text. It seems that projectivity and syntax co-operate to allow us to use long sentences, but keep the mean DD within an acceptable range.

5 Conclusions

We have investigated the probability distributions of dependency distances in six texts extracted from a Chinese dependency treebank. The results reveal that the data can be well captured by the right truncated Zeta distribution. To see whether the conclusion holds only for a natural language, we constructed two samples with randomly generated governors, but with the same texts. The most random one needs the addition of a further parameter, the other one abides by the right truncated Zeta distribution. The paper also presents a study on sequential plots and mean dependency distances of six texts with three analyses (a syntactic and two random ones). The results show that syntax plays an important role in minimizing the (mean) dependency distance and in turn for the minimization of decoding effort. The shorter the

dependency distances, the smaller is the decoding effort of the sentence (Gibson 2000). Thus, the problem has its psycholinguistic and synergetic counterparts.

Considering the importance of dependency distance for any linguistic applications based on the dependency principle, the study contributes to a quantitative understanding of dependency syntax. Further research in projectivity is needed to investigate why RL2 abides by the same regularity as a natural text, while it has a greater mean DD than a natural (syntactic) text.

Acknowledgements

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Russizismen im deutschen Wortschatz

Oxana Kotsyuba, Dortmund[1]

Abstract. The history of the German language is a history depicting the influence of foreign languages on German, as has been portrayed in different publications on the influence of the English, French, and Italian languages. The influence of other modern languages, among them the Russian language, has not been analysed to a great extent. This paper, based on gained data, intends to determine whether the Piotrowski-Law applies to the process of word-borrowing from Russian into German.

Keywords: Borrowings, German, Russian, Piotrowski-law

Das Piotrowski-Gesetz als Modell für Entlehnungsprozesse

Der vorliegende Beitrag ist einer weiteren Bestätigung eines Sprachgesetzes, in diesem Fall des Piotrowski-Gesetzes, gewidmet. Es wurde am Beispiel der Übernahme von Russizismen in die deutsche Sprache erneut erprobt. Um dies durchzuführen, wurde eigens für diese Untersuchung ein neues Korpus erarbeitet.

Im Folgenden wird zunächst das Prinzip des Piotrowski-Gesetzes dargestellt. ”Unter dem Piotrowski-Gesetz verstehen wir die hypothetische Aussage über den zeitlichen Verlauf der Veränderungen einer beliebigen sprachlichen Entität” (Altmann 1983:59). Das Gesetz ist nach dem sowjetischen Linguisten Raimond Genrichowitsch Piotrowski benannt. Dieses logistische Gesetz ist auf verschiedene Formen des Sprachwandels anwendbar, wobei unter Sprachwandel der Veränderungsprozess von Sprachelementen und Sprachsystemen in der Zeit verstanden wird. Es lassen sich drei unterschiedliche Formen des Sprachwandels unterscheiden:

- der vollständige Sprachwandel, bei dem alte Formen vollständig durch die neuen Formen ersetzt werden (z.B. *was* zu *war*);
- der unvollständige Sprachwandel, bei dem sich die neuen Formen und Wörter nur in einem begrenztem Maß durchsetzen (z.B. Fremdwörter);
- der reversible Sprachwandel, bei dem neue Formen und Wörter aufkommen, sich ausbreiten und dann wieder verschwinden (z.B. die e-Epithese im Deutschen).

Bei Entlehnungen wird der schon vorhandene Wortschatz einer Sprache ergänzt oder auch teilweise ersetzt, aber nie ganz verdrängt. Also handelt es sich dabei um den Typ einer unvollständigen Sprachänderung. Dafür wurde folgende mathematische Funktion entwickelt:

(1) $$p_t = \frac{c}{1 + ae^{-bt}}$$

(zur Begründung und Ableitung des Modells vgl. Altmann 1983: 60f, Formel 7). Es handelt

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sich dabei um ein Wachstumsmodell vom logistischen Typ, wie es in der Biologie, Soziologie, Ökonomie oder in der Bevölkerungsdynamik seit langem Anwendung findet.

Das Piotrowski-Gesetz beschreibt allgemein den zeitlichen Verlauf der Veränderung sprachlicher Einheiten. Mithilfe dieses Gesetzes ist es möglich vorauszusagen, wie ein begonnener Sprachwandel weiter verläuft. Eine sehr wichtige Voraussetzung ist, dass sich die Bedingungen, unter denen dieser Sprachwandel stattgefunden hat, nicht wesentlich verändern, sondern gleich bleiben.

Eine modellhafte Erprobung und Überprüfung des Piotrowski-Gesetzes findet sich in vielen empirischen Untersuchungen zum Sprachwandel im Deutschen. Die Annahme, dass die Entlehnungsprozesse tatsächlich dem oben genannten Modell entsprechen, konnte für Entlehnungen aus Latein, Französisch, Niederdeutsch, Niederländisch, Italienisch, Spanisch, Griechisch und weitere Sprachen bestätigt werden (vgl. Best & Altmann 1986). Später sind die gewonnenen Ergebnisse von Best (2001b) anhand einer weiteren Datenbasis überprüft worden und das Modell hat sich auch dabei bewährt. Der Einfluss der Sprachen, von denen das Deutsche über Jahrhunderte hinweg immer wieder Wörter entlehnt hat, ließ die Sprachwandelprozesse in diesen Untersuchungen den typischen S-förmigen Verlauf nehmen.

Auch der englische Einfluss auf das Deutsche wurde untersucht und konnte anhand des Piotrowski-Gesetzes nachvollzogen werden (vgl. Best & Altmann 1986; Best 2001b, 2003b; Körner 2004).

Der Zuwachs der deutschen, lateinischen und slawischen Wörter im Ungarischen wurde in der Arbeit von Beöthy & Altmann (1982) erforscht und die Gesetzmäßigkeit des Verlaufs von Entlehnungsprozessen wurde anhand des Piotrowski-Gesetzes erneut bestätigt.

Im Artikel von Helle Körner (2004) wird das logistische Gesetz unter anderem anhand der Datenbasis der slawischen Wörter überprüft. Das Korpus enthält 44 Slawismen. Die Autorin fasst sämtliche slawischen Sprachen, aus denen Wörter übernommen worden sind, unter dem Sammelbegriff *Slawisch* zusammen, um eine Datenauswertung zu ermöglichen. Andernfalls wären für jede einzelne dieser Sprachen zu wenige Belege vorhanden gewesen (vgl. Körner 2004:40). Entlehnungen aus dem Russischen sind nicht gesondert betrachtet worden.

In Bezug auf den slawischen bzw. russischen Einfluss im Deutschen ist die Arbeit von Karl-Heinz Best (2003a) nennenswert. Der Autor führt zwei Auswertungsverfahren durch. Zum einen wird der Prozess der Übernahme slawischer Wörter insgesamt anhand des Piotrowski-Gesetzes unter Beweis gestellt. Zum anderen wird die Gesetzmäßigkeit des Verlaufs von Entlehnungen aus dem Russischen überprüft. Für die übrigen slawischen Sprachen stehen nicht genügend Daten zur Verfügung. Die Datenbasis dieser Untersuchung enthält 124 slawische Entlehnungen, darunter 56 Lehnwörter aus dem Russischen. Bei der Auswertung der Daten stößt Best auf das Problem der auffallend hohen Zunahme slawischer Lehnwörter im 20. Jahrhundert, für die ausnahmslos der russische Einfluss verantwortlich ist. Für die späteren Untersuchungen schlägt der Autor vor, von den Lehnwörtern des 20. Jahrhunderts diejenigen zu streichen, die unter politischem bzw. ideologischem Einfluss entstanden. Diese Lehnwörter würden aufgrund der politischen Entwicklung in Deutschland und in Osteuropa in den 1990er Jahren nur noch relativ kurze Zeit eine Rolle in der deutschen Sprache spielen (vgl. Best 2003a: 469).

Beide Autoren, Körner und Best, weisen darauf hin, dass die Korpora für slawische bzw. russische Entlehnungen erweitert werden sollten, damit die Ergebnisse der Untersuchungen als zuverlässiger und repräsentativer angesehen werden könnten. Außer diesen zwei erwähnten Arbeiten sind anscheinend keine anderen Untersuchungen zur Gesetzmäßigkeit des Verlaufs der Entlehnungsprozesse aus den slawischen Sprachen bzw. aus dem Russischen vorhanden. Es gibt also hinreichend Gründe dafür, zu versuchen, die Datenbasis zu erweitern

und danach die Gültigkeit des Piotrowski-Gesetzes erneut zu prüfen. Dieses Ziel verfolgt die vorliegende Untersuchung.

Methodik der Untersuchung

Bei der Durchführung der vorliegenden Untersuchung werden folgende methodische Aspekte berücksichtigt:

- das lexikographische Fundament des Korpus;
- qualitative Bestandteile der Datenbasis;
- Behandlung von Problemen bei Zeitangaben;
- Behandlung von Problemen bei der Vermittlersprache.

Im Folgenden werde ich auf einzelne Aspekte der Methodik näher eingehen, um den Prozess des Zusammenstellens des Korpus darzustellen.

Das lexikographische Fundament des Korpus

Das Untersuchungskorpus für die vorliegende Untersuchung wurde mithilfe der lexikographischen Analyse verschiedener Fremdwörterbücher und Fachbücher zusammengestellt. Als Ausgangspunkt für die Zusammenstellung des Korpus dienten folgende Untersuchungen:

- die Dissertation *Russisches lexikalisches Lehngut im deutschen Wortschatz* von Siegfried Kohls (1964)
- die Untersuchung *Ostslawische lexikalische Elemente im Deutschen* von Efim Opel'baum (1971)
- eine alphabetische Zusammenstellung der im Deutschen verwendeten Wörter aus slawischen und anderen Sprachen von Klaus Müller aus dessen Buch *Slawisches im deutschen Wortschatz* (1995).

Die lexikographische Fixierung entlehnter russischer Wörter und die Vervollständigung des Korpus wurden im Weiteren durch folgende Quellen ergänzt und erweitert:

- das *Etymologische Wörterbuch der deutschen Sprache* von Friedrich Kluge (1999)
- das *Etymologische Wörterbuch des Deutschen* von Wolfgang Pfeifer (1993)
- die Auswertung der *Brockhaus Enzyklopädie* (1989).

Russische Entlehnungen wurden auch in den Arbeiten von Hans Holm Bielfeldt (1963; 1965; 1982) und im *Altrussischen Lexikon* von Erich Donnert (1988) untersucht. Aus diesen Werken sind ebenfalls Entlehnungen in mein Korpus eingeflossen.

Qualitative Bestandteile der Datenbasis

Die Basis für die vorliegende Untersuchung bilden 262 Entlehnungen aus dem Russischen. Das Korpus enthält ausschließlich die Übernahmen aus dem Russischen in den deutschen Wortschatz. Zu dem zu untersuchenden lexikalischen Lehngut gehören assimilierte und nicht assimilierte Lehnwörter russischer Herkunft sowie russischer Vermittlung.

Russische geographische Bezeichnungen (z.B. *Wolga*), Personennamen (z.B. *Iwan*), Eigennamen (z.B. *Aeroflot*), spezielle russische Fachausdrücke und nur gelegentlich belegte russische Wörter wie auch phraseologische Redewendungen sind nicht berücksichtigt worden.

Was das entlehnte Wortgut des 20. Jahrhunderts angeht, so enthält die Datenbasis einige

Sowjetismen, die im politischen Wortschatz eine Rolle spielten bzw. spielen (von *Bolschewik*, *Kolchos(e), Komsomol, Kulak, Sowjet* bis hin zu *Glasnost* und *Perestrojka* aus den 1980er Jahren). Bildungen aus Eigennamen werden nur ausnahmsweise aufgenommen (z.B. *Stalinismus*, *Trotzkismus* usw.). Die große Zahl weiterer Ableitungen (z.B. *Bykow-Methode*, *Honnecke-Bewegung*, *Lenin-Preis* usw.) bleibt unberücksichtigt.

Die Lehnprägungen, darunter vor allem Lehnübersetzungen und Lehnbedeutungen, die den russischen Einfluss zur DDR-Zeit geprägt haben, sind in Anlehnung an Best (2003a) aus zwei Gründen nicht in die Datenbasis übernommen worden. Zum einen, da diese Wörter nur auf dem DDR-Territorium verbreitet waren und in der Bundesrepublik entweder gar nicht bekannt waren oder nur selten benutzt wurden. Zum anderen wird ein erheblicher Teil dieses Wortschatzes im Deutschen keine Zukunft mehr haben, da er bereits in Vergessenheit geraten ist (vgl. Hellmann 1990: 267).

Ableitungen wie *kolchosieren* oder *jarowiesieren* sowie umgangssprachliche Lehnwörter (*dawaj*, *nitschewo*, *pascholl*, *stupaj*, *stoj*), die meistens als Okkasionalismen verwendet werden, werden nicht in die Datenbasis übernommen.

Die Behandlung von Problemen bei Zeitangaben

Die untersuchten Wörter sind zu verschiedenen Zeitpunkten in den deutschen Wortschatz eingegangen. Für eine systematische Auswertung des Korpus sind die genauen Angaben über das Jahrhundert der Übernahme notwendig.

In die Datenbasis wurden nur die Lehnwörter übernommen, bei denen das Jahrhundert der Übernahme ausreichend genau bestimmbar ist. Die Zeit der Übernahme wird in der Regel aufgrund der Erstbelege im Deutschen nach dem derzeitigen Forschungsstand beschrieben. An dieser Stelle muss ausdrücklich darauf hinwiesen werden, dass nicht alle Forscher das Datum der Übernahme der in meinem Korpus angeführten Wörter gleich bestimmen. Zum Feststellen der Datierbarkeit wurden insgesamt drei Untersuchungen von Opel'baum (1971), Kohls (1964) und Müller (1995) herangezogen. Wenn die Angaben in den ersten beiden Fachbüchern eine eindeutige Zuordnung zu einem Jahrhundert aufwiesen und übereinstimmten, wurden diese Angaben ohne nochmalige Überprüfung durch andere Fach- und Wörterbücher übernommen. Wenn aber Unstimmigkeiten auftraten, wurden das Buch von Klaus Müller sowie die Wörterbücher von Kluge (1999) und Pfeiffer (1993) hinzugezogen. Wenn zwei der drei verwendeten Fach- oder Wörterbücher Übereinstimmungen zeigten, wurde diese Datierung als eindeutige Angabe gewertet. Wenn aber Widersprüche und Abweichungen auftraten, wurde das Lehnwort aus der Datenbasis ausgeschlossen.

In Anlehnung an Best (2001a) sind die Entlehnungen, die zwei Jahrhunderten zugeordnet sind, wie z.B. "16./17. Jahrhundert", dem erstgenannten Zeitraum zugerechnet worden. Die Angaben "um 1700" werden dem folgenden, 18. Jahrhundert zugewiesen (vgl. Best 2001a:8). Bei Wörtern, die aus anderen Sprachen über das Russische vermittelt wurden, wird nur die Zeitangabe des Übergangs ins Deutsche angegeben. Undatierte Entlehnungen wurden nicht berücksichtigt.

Die Lehnwörter im Korpus werden im Allgemeinen Jahrhunderten zugewiesen (z.B. 17. Jh.; 1. Hälfte 18. Jh.; Mitte 19. Jh.; 2. Hälfte 20. Jh.).

Die Behandlung von Problemen bei der Vermittlersprache

Für die Auswertung etymologischer Wörterbücher gibt es zwei Herangehensweisen: Entweder wird die Vermittlersprache, d.h. die Sprache, über die ein Wort ins Deutsche gelangt ist, berücksichtigt, oder aber die Herkunftssprache, d.h. die Sprache, aus der ein Wort ur-

sprünglich stammt. Je nach Verfahren ergeben sich also andere Zuordnungen. In Anlehnung an Best (2001a: 8) war für diese Auswertung lediglich die Vermittlersprache ausschlaggebend.

Einige Lehnwörter, die bei Siegfried Kohls (1964) als Entlehnungen aus dem Russischen und bei Efim Opel'baum (1971) und Klaus Müller (1995) als ukrainische Entlehnungen verzeichnet sind, wurden nicht in die Datenbasis übernommen, z.B. *Bandura, Baschtan, Baschtanik, Borschtsch, Duma* "ukrainisches Volkslied", *Haidamaken, Hopack, Kalamaika, Kelim (Kilim), Kobsa, Kobsar, Kosak* "ukrainischer Volkstanz", *Rada und Hetman* (vgl. Opel'baum 1971: 238, Müller 1995: 23).

Nicht aufgenommen wurden auch Wörter, bei denen die russische Herkunft bisher angenommen wurde, doch aufgrund neuer Forschungen nicht gesichert erscheint (z.B. *Grippe*).

Entlehnungen aus dem Englischen, die auf dem ehemaligen DDR-Territorium durch das Russische vermittelt wurden, wurden in die Datenbasis ebenfalls nicht übernommen, weil sie keine allgemeine Verbreitung in der deutschen Sprache gefunden haben und deshalb für diese Untersuchung nicht repräsentativ sind. Die Lehnwörter, die ursprünglich aus den türk-tatarischen, mandschu-tungusischen, kaukasischen und semitischen Sprachen stammen und bei denen das Russische als Vermittlungssprache auftritt, wurden allerdings in die Datenbasis übernommen, sofern die Datierung klar war.

Aufgenommen sind weitere Wörter, die vom Russischen vermittelt sind; dabei kann es sich um eine Rückentlehnung handeln (z.B. *Budka, Duma "Ratsversammlung, Stadthaus", Kapusta, Knute, Polk, Sterlet*).

Auswertung

Es wird von der Annahme ausgegangen, dass der Prozess der Übernahme von Fremdwörtern ebenso wie alle anderen Sprachwandelprozesse gesetzmäßig verläuft und dabei dem sogenannten Piotrowski-Gesetz folgt. Anhand der zur Verfügung stehenden Daten wurde geprüft, ob dies sich auch für den Einfluss der russischen Sprache auf das Deutsche nachweisen lässt. Das hier angewendete Testverfahren hat G. Altmann (1983: 74ff) beschrieben.

Für die russischen Entlehnungen kommen nach der Auszählung der zusammengestellten Datenbasis und der anschließenden Berechnung folgende Werte zustande (vgl. Tabelle 1).

Tabelle 1
Übernahme russischer Entlehnungen ins Deutsche (10.-20. Jh.)

Jahrhundert	**t**	**n**	**n (kumuliert)**	**p (berechnet)**
10.	1	1	1	0,68
11.	2	1	2	1,33
12.	3	0	2	2,59
13.	4	5	7	5,03
14.	5	4	11	9,73
15.	6	7	18	18,68
16.	7	23	41	35,27
17.	8	30	71	64,66
18.	9	21	92	112,77
19.	10	105	197	182,10
20.	11	65	262	265,73
A = 1470.5335	b = 0.6698	c = 512.4192	D = 0.99	

- *t* gibt die Nummer der zu untersuchenden Jahrhunderte an;

- *n* gibt die Anzahl der ausgezählten Wörter für das entsprechende Jhd. an (beobachtete Werte);
- *n (kumuliert)* gibt die Summe aller bis zum entsprechenden Jahrhundert übernommenen Wörter an (kumulierte Werte);
- *p (berechnet)* führt theoretisch nach der Funktion *p(t)* von Altmann berechnete Werte für das entsprechende Jahrhundert auf.

Die Berechnung der Daten erfolgte mithilfe des Programms NLREG Version 6.3. Eine Demonstrationsversion dieses Programms kann man im Internet von der Seite http://www.nlreg.com/ herunterladen.

- *a, b* und *c* sind Parameter des logistischen Gesetzes
- *c* gibt den berechneten Wert für den Sprachwandel an, der anzeigt, gegen welchen Wert der Sprachwandel strebt. Dabei ist unter *c* nicht ein absoluter Wert zu verstehen, der tatsächlich angibt, wie viele Wörter im Höchstfall aus der jeweiligen Sprache übernommen werden, sondern nur eine Tendenz, die je nach Datenbasis variiert;
- *D* ist der Determinationskoeffizient. Je größer *D* ist, desto besser ist die Anpassung. Es soll $D \geq 0.80$ gelten, um sagen zu können, dass das Modell den Sprachwandelprozess in annehmbarer Weise wiedergibt. In unserem Fall handelt es sich um den Wert $D = 0.99$. Dies bedeutet eine sehr gute Anpassung.
- Diese Erklärungen gelten auch für die nächste Tabelle.

Nach Einsetzung der errechneten Parameter in die Formel (1) ergibt sich für die Übernahme der Russizismen im deutschen Wortschatz folgender Term:

$$p_t = \frac{512{,}4192}{1+1470{,}5335e^{-0{,}6698t}}.$$

Die Übernahme russischer Wörter ins Deutsche wird in der folgenden Graphik (vgl. Abb. 1) dargestellt; dabei wurde die Linie für die berechneten Werte über den Beobachtungszeitraum hinweg durchgezogen, um eine Vorstellung davon zu geben, wie die zukünftige Entwicklung sein könnte.

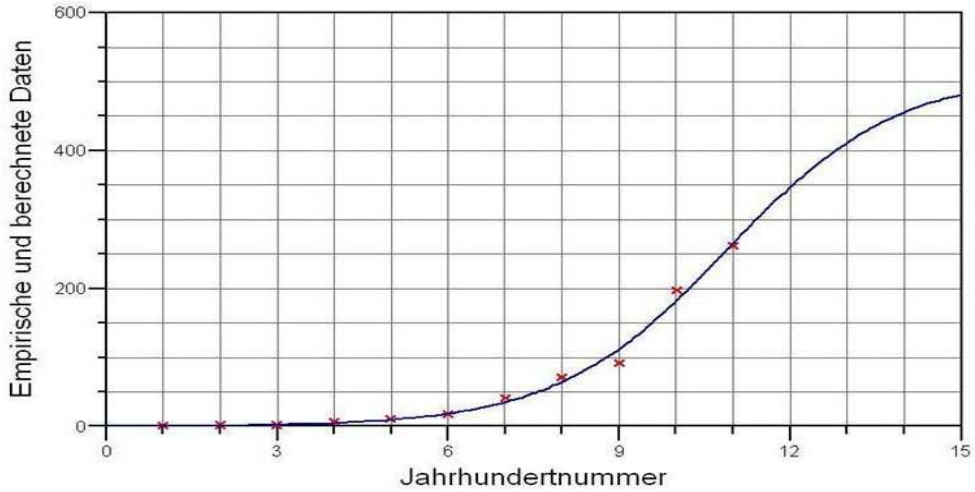

Abbildung 1. Übernahme russischer Wörter ins Deutsche (10. – 20. Jh.)

Die y-Achse bezeichnet die Anzahl der Wörter, auf der x-Achse wird die Zeit (in Jahrhunderten) eingetragen. Die durchgehende Linie gibt in Übereinstimmung mit Formel 1 den Ver-

lauf der berechneten Werte an, die Punkte stellen die empirischen Werte[2] dar.

Die Grafik spiegelt eine gute Annäherung zwischen den berechneten und den beobachteten Daten wider, die sich an den geringen Abständen zwischen den Punkten und der Kurve der Grafik zeigt. Aus der Tabelle und aus der Grafik wird deutlich, dass es sich hierbei um einen momentan noch nicht abgeschlossenen Sprachwandelprozess handelt. Das erkennt man z.B. daran, dass der letzte gemessene Wert für *n (kumuliert)* noch weit entfernt von der hypothetischen Asymptote liegt, die durch Grenzwert $c = 512{,}4192$ gegeben ist. An der Kurve der berechneten Werte ist die Asymptote ab dem 23. Jahrhundert erkennbar. Eben ab diesem Wert verflacht die Kurve zunehmend.

Die Abweichungen der empirischen und der berechneten Werte im Zeitraum zwischen dem 17. und dem 19. Jahrhundert sind auf die Schwierigkeiten bei der Datierung der Lehnwörter zurückzuführen. Die meisten Schwierigkeiten bereitete die Lexik, die vermutlich aus dem 18. Jahrhundert stammt, die allerdings von verschiedenen Forschern verschiedenen Jahrhunderten zugeordnet wurde. 33 Lehnwörter wurden deswegen vorerst aus der Datenbasis ausgeschlossen. Damit der mathematische Fehler möglichst klein bleibt, verrutscht die Kurve etwas nach unten, um den Abstand zum empirischen Wert für das 18. Jahrhundert zu reduzieren. Das heißt, nicht die Werte für das 17. und das 19. Jahrhundert liegen über der Kurve, sondern die Kurve nimmt ihren Weg unter diesen Werten.

Wenn allerdings die oben angesprochenen 33 Entlehnungen mit der unsicheren Datierung dem 18. Jahrhundert zuordnet werden, erhält man das durch das Piotrowski-Gesetz vorausgesagte Ergebnis. Dies spricht dafür, dass diese Lehnwörter aus dem 18. Jahrhundert stammen. Die Auswertung der Datenbasis mit den jetzt dem 18. Jahrhundert zugeordneten Entlehnungen und die anschließende Berechnung ergeben schließlich für das Russische die in Tabelle 2 angegebenen Daten.

Tabelle 2
Übernahme russischer Entlehnungen ins Deutsche (10.- 20. Jh.)
mit dem veränderten Wert für das 18. Jahrhundert

Jahrhundert	**t**	**n**	**n (kumuliert)**	**p (berechnet)**
10.	1	1	1	0.27
11.	2	1	2	0.62
12.	3	0	2	1.4
13.	4	5	7	3.2
14.	5	4	11	7.25
15.	6	7	18	16.2
16.	7	23	41	35.29
17.	8	30	71	72.75
18.	9	54	125	135.83
19.	10	105	230	218.85
20.	11	65	295	298.73
a = 3527.6687	b = 0.8267		c = 417.1549	D = 0.99

Auch in diesem Fall bestätigt der Determinationskoeffizient $D = 0.99$, dass es sich um eine sehr gute Anpassung des logistischen Gesetzes handelt.

[2] Bei der nächsten Grafik gilt diese Legende ebenso wie die Beschriftung der Achsen. Die Zuordnung von *t* zu den Jahrhunderten kann jeweils aus den Tabellen abgelesen werden.

Aus den errechneten Parametern und dem ermittelten Grenzwert ergibt sich für die Übernahme der Russizismen im deutschen Wortschatz folgender Term:

$$p_t = \frac{417{,}1549}{1 + 3527{,}6687 e^{-0{,}8267t}}$$

Die Übernahme russischer Wörter ins Deutsche stellt sich grafisch wie in Abb. 2 dargestellt dar.

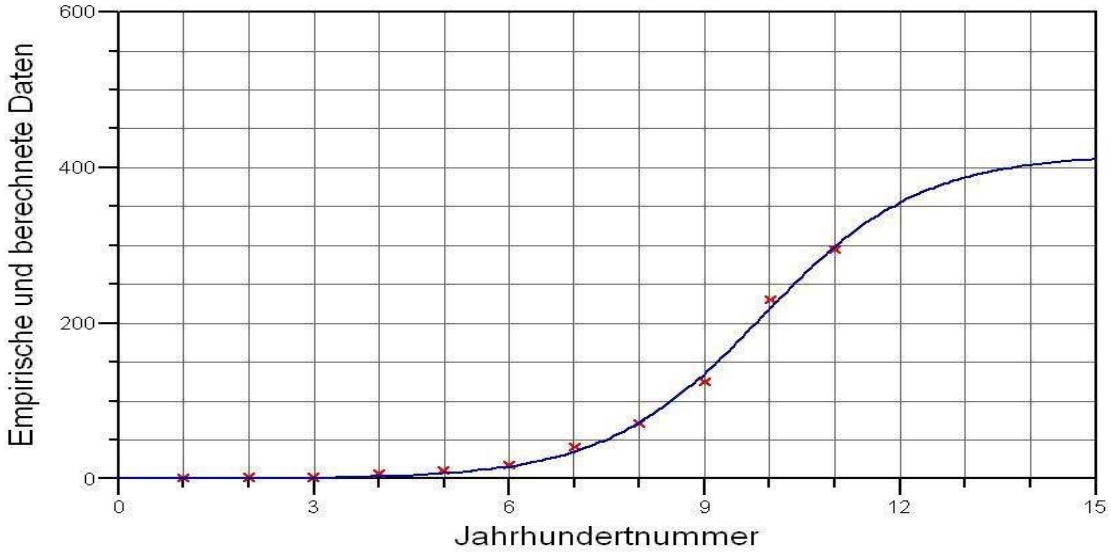

Abbildung 2. Übernahme russischer Entlehnungen ins Deutsche (10.- 20. Jh.) mit dem veränderten Wert für das 18. Jahrhundert

Die Verbesserung spiegelt sich in der Grafik deutlich wider: Die Punkte (empirische Werte) liegen wesentlich besser auf der Kurve. Betrachtet man die Grafik, so sieht man, wie die Kurve schon ab dem 21. Jahrhundert zunehmend verflacht und sich asymptotisch dem c-Wert nähert. Dies verweist darauf, dass bei gleichbleibenden Umständen in der Zukunft vermutlich nur eine schwache Übernahme der russischen Lehnwörter erfolgen, und der Übernahmeprozess bald (ceteris paribus) abgeschlossen sein wird.

Die Erhöhung des Datensatzwertes für das 18. Jahrhundert bewirkt, dass die Tendenz, nach der Wörter aus dem Russischen ins Deutsche übernommen werden, nicht mehr so steil wie in der ersten Betrachtung ausfällt. Dort lag der Datenpunkt für das 18. Jahrhundert weiter von den Werten für das 19. und das 20. Jahrhundert entfernt, was eine höhere Kurvensteigung und dementsprechend ihr späteres Abflachen bedeutet. Da der Wertunterschied jetzt kleiner geworden ist, kann die Steigung geringer bleiben und die Grafikkurve früher abflachen.

In den empirischen Werten für das 19. und das 20. Jahrhundert spiegeln sich die rasanten politischen, wirtschaftlichen und wissenschaftlichen Entwicklungen des 19. und 20. Jahrhunderts in Russland wieder. Gleichzeitig haben die politischen Veränderungen in Europa bzw. in der ehemaligen DDR und in den ehemaligen Ostblockstaaten um 1990 herum die lexikalischen Einflüsse besonders des Russischen auf das Deutsche stark beeinflusst und wesentlich modifiziert. Der extreme Zuwachs der russischen Wörter im 19. und 20. Jahrhundert lässt sich durch den gewaltigen politischen und wirtschaftlichen Aufschwung erklären. Zu dieser Zeit kommt es zu einer wichtigen Reform – die Befreiung der Bauern von Fronen (*Barschtschina*) und Abgaben an die Gutsherren. Als wichtigste Quellen des neuen russischen Lehngutes bleiben Reiseberichte sowie kommerzielle und diplomatische Urkunden. Hinzu kommen noch

russische literarische Werke, die seit Anfang des 19. Jahrhunderts ins Deutsche übersetzt wurden. Bei den Entlehnungen aus dem 20. Jahrhundert handelt es sich um einen Wortschatz, der auf die politische und ideologische Dominanz der Sowjetunion in Osteuropa zurückzuführen ist.

Ergebnis

Das logistische Gesetz in der unvollständigen Form konnte mit einem sehr guten Ergebnis an beiden Datensätzen bestätigt werden. Dies unterstützt die theoretischen Annahmen zu diversen Sprachwandelprozessen. Problematisch ist dabei die Betrachtung des Grenzwertes *c*. Zur Schwierigkeit der Interpretation des Grenzwertes *c* sagt Karl-Heinz Best:

> ”Es spricht daher tatsächlich alles dagegen, die Schätzwerte für *c* als genaue Werte für den Zuwachs zu verstehen. Sie sind rechnerische Größen, die sich ergeben, wenn man untersucht, ob die Formel für den unvollständigen Sprachwandel ein geeignetes Modell für die jeweilige Datenbasis darstellt. Wenn *c* interpretiert werden soll, so immer nur bezogen auf die Wörterbücher, die die Daten für den Entlehnungsprozess geliefert haben. Ein Schluss auf das Lexikon der Sprache insgesamt ist nur denkbar, wenn man berücksichtigt, dass jedes Wörterbuch einen unterschiedlichen Ausschnitt aus dem Vokabular der Sprache darbietet und wenn man diesem Wörterbuch eine gewisse Repräsentativität für die Sprache zubilligen kann.” (Best 2001c: 14)

Der Wert *c* gibt also an, gegen welchen Zielwert der Entlehnungsprozess strebt. Dieser Wert wird nur als Prognose für den betrachteten Prozess gewertet.

Die vorliegende Untersuchung zur Gesetzmäßigkeit des Verlaufs von Entlehnungsprozessen kann für den russischen Einfluss auf das Deutsche als durchaus repräsentativ gelten. In beiden Fällen konnte der typische S-förmige Verlauf eines unvollständigen Sprachwandelprozesses bzw. der Fremdwortübernahme in der Sprache beobachtet werden, wie dies bereits unter anderem von Best & Altmann (1986), Best (2001a, 2001b, 2003a, 2003b) gezeigt wurde. Das logistische Gesetz wird somit auch in seiner Anwendung auf Entlehnungen aus dem Russischen bestätigt. Die durchgeführte Untersuchung gibt nicht nur einen rein historischen Überblick, sondern auch die Möglichkeit, sich einen Ausblick auf potentielle Weiterentwicklungen einzelner Entlehnungsprozesse – in diesem Fall über den Entlehnungsprozess aus dem Russischen – zu verschaffen.

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COSMAS: (Corpus Search, Management and Analysis System), Version 3.4.2, http://www.ids-mannheim.de/cosmas2/.

NLREG: Nonlinear Regression Analysis Program. Version 6.3. Phillip H. Sherrod. Copyright (c) 1992-2005

Glottometrics 15, 2007, 24-27

Zur Entwicklung des Wortschatzes der Elektrotechnik, Informationstechnik und Elektrophysik im Deutschen

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Abstract. The purpose of this paper is to present some further evidence for the validity of the logistic law in the development of the dictionary. To this end we test some data on the increase of terms and signs in a technical language presented by Warner (2007).

Entwicklung des Wortschatzes einer Sprache

Will man sich mit der Entwicklungsdynamik des Wortschatzes einer Sprache befassen, muss man eine erhebliche Datenarbeit durchführen oder auf eine solche zurückgreifen können. Das Ziel, den gesamten Wortschatz zu erfassen, scheint trotz Computern und Datenbänken noch in weiter Ferne zu liegen. Hauptproblem dabei ist, dass nur für recht kleine Ausschnitte des Wortschatzes zeitliche Angaben zu bekommen sind. Für das Deutsche kann man sagen, dass hauptsächlich die bekannten etymologischen Wörterbücher als Quellen in Betracht kommen (Duden. Herkunftswörterbuch; Kluge; Pfeifer). Ihr Stichwortbestand erreicht im besten Fall nur wenig über 20000 Wörter, die aber keineswegs alle datiert sind. Eine weitere Quelle mit datierten Angaben zum deutschen Wortschatz ist Kirkness (1988), wo man Angaben zu ca. 9000 Fremdwörtern findet. Folgt man den üblichen Schätzungen, die den deutschen Wortschatz auf 300000-500000 Wörter beziffern (Best 2000), so heißt das, dass bestenfalls für rund 10% zeitliche Angaben gemacht werden können. Auf dieser Basis konnte sowohl für die Entwicklung des deutschen Erbwortschatzes als auch für die Übernahmen aus verschiedenen Fremdsprachen gezeigt werden, dass diese Prozesse immer dem logistischen Gesetz folgen (vgl. dazu u.a. die Überblicksartikel Best 2001, Körner 2004).

In einem Fall ist es gelungen, auf anderem Wege zu brauchbaren Daten zu kommen. So konnte die Entwicklung des Computerwortschatzes im Deutschen aufgrund von Untersuchungen von Busch (2004, 2005) und Wichter (1991) nachvollzogen werden, wobei vereinzelte Beobachtungen zu Erstbelegen einschlägiger Wörter, vor allem aber Angaben zur Entwicklung der betreffenden Fachwörterbücher, genutzt werden konnten (Best 2006).

Zum Fachwortschatz der Elektrotechnik, Informationstechnik und Elektrophysik

Während im Fall des Computerwortschatzes annähernd der gesamte Fachwortschatz in seiner Entwicklung bis Ende der 1980er Jahre erfasst werden konnte, geht es in diesem Beitrag um einen Ausschnitt aus einem weiteren Fachwortschatz: die Wortschatzentwicklung der Elektrotechnik, Informationstechnik und Elektrophysik soll daraufhin getestet werden, ob sie entsprechend dem logischen Gesetz (oft auch: Piotrowski-Gesetz) verläuft. Daten zu diesem Prozess liegen seit kurzem durch das Wörterbuch von Warner (2007) vor, eine Darstellung, die am Ende des Buches eine Zeittafel enthält, der man entnehmen kann, welche Wörter und Zeichen wann entstanden sind. Die Auswertung dieser Zeittafel ist in der folgenden Tabelle wiedergegeben:

Tabelle 1

Wortschatzentwicklung der Elektrotechnik, Informationstechnik und Elektrophysik					
Zeit	neue Wörter beobachtet	Wörter kumuliert	Zeit	neue Wörter beobachtet	Wörter kumuliert
3. Jhd. v. Chr.	2	2	16. Jhd.	8	23
2. Jhd. v. Chr.	1	3	17. Jhd.	26	49
1. Jhd. v. Chr.	0	3	1700-1749	24	73
1. Jhd. n. Chr.	2	5	1750-1799	32	105
2. Jhd.	1	6	1800-1849	48	153
3. Jhd.	0	6	1850-1874	32	185
4. Jhd.	0	6	1875-1899	105	290
5. Jhd.	0	6	1900-1909	41	331
6. Jhd.	0	6	1910-1919	41	372
7. Jhd.	0	6	1920-1929	51	423
8. Jhd.	0	6	1930-1939	55	478
9. Jhd.	0	6	1940-1949	12	490
10. Jhd.	0	6	1950-1959	29	519
11. Jhd.	0	6	1960-1969	21	540
12. Jhd.	7	13	1970-1979	13	553
13. Jhd.	0	13	1980-1989	9	562
14. Jhd.	0	13	1990-1999	8	570
15. Jhd.	2	15	2000-	5	575

Dass es sich dabei nicht um den gesamten Fachwortschatz handelt, ist klar: Warner gibt z.B. an, wann welche Kompositionskonstituente (wie z.B. „giga-„, nano-“) eingeführt wurde; damit sind aber ja nicht alle Wörter, die diese Konstituenten enthalten, erfasst. In der Tabelle sind außerdem Symbole für Konstanten nur einmal erfasst.

Die Hypothese, die hier geprüft werden soll, lautet: Der Wortschatzzuwachs entwickelt sich gemäß dem logistischen Gesetz. Die folgende Tabelle 2 zeigt daher die Anpassung dieses Gesetzes; die Entwicklung folgt dem Modell (1) für den unvollständigen Sprachwandel (Altmann 1983: 60f.):

$$(1) \qquad p = \frac{c}{1 + ae^{-bt}}.$$

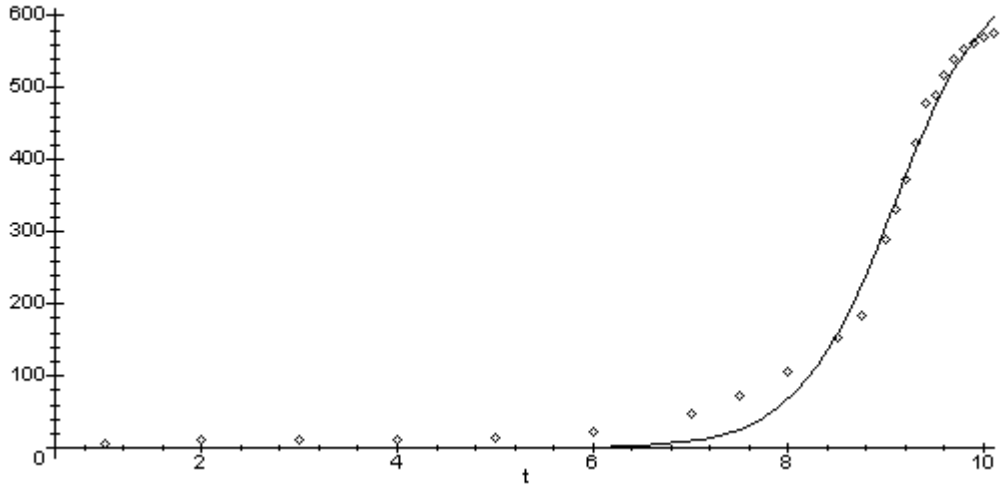
Die Anpassung des Modells wurde mit der Software NLREG durchgeführt.

Da für die Zeit bis zum 2. Jahrhundert nach Christus nur ganze 6 Wörter angegeben sind und bis zum 11. Jahrhundert einschließlich keine weiteren neuen Termini nachgewiesen wurden, sind in Tabelle 2 und bei der Anpassung des Modells nur die Daten ab dem 11. Jahrhundert aufgenommen. Für das 11. Jahrhundert werden die 6 altüberlieferten Wörter angesetzt. t steht immer für das vollendete Zeitintervall.

Legende zur Tabelle 2: a, b *und* c sind die Parameter des Modells; c gibt an, auf welchen Zielwert der beobachtete Prozess hinsteuert. Die Anpassung an die beobachteten Daten ist mit $D = 0.99$ sehr gut, wie auch die folgende Graphik zeigt. (Der Determinationskoeffizient D soll mindestens 0.80 erreichen, um eine gute Übereinstimmung zwischen Modell und Beobachtungswerten anzuzeigen; er kann aber nicht größer als $D = 1.00$ werden.)

Tabelle 2

Wortschatzentwicklung der Elektrotechnik, Informationstechnik und Elektrophysik							
t	Zeit	Wörter kumuliert	Wörter berechnet	*t*	Zeit	Wörter kumuliert	Wörter berechnet
1	11. Jhd.	6	0.00	9.1	1900-1909	331	344.91
2	12. Jhd.	13	0.00	9.2	1910-1919	372	379.04
3	13. Jhd.	13	0.00	9.3	1920-1929	423	412.29
4	14. Jhd.	13	0.02	9.4	1930-1939	478	444.04
5	15. Jhd.	15	0.16	9.5	1940-1949	490	473.79
6	16. Jhd.	23	1.25	9.6	1950-1959	519	501.16
7	17. Jhd.	49	9.56	9.7	1960-1969	540	525.92
7.5	1700-1749	73	25.89	9.8	1970-1979	553	548.00
8	1750-1799	105	67.31	9.9	1980-1989	562	567.42
8.5	1800-1849	153	158.74	10	1990-1999	570	584.29
8.75	1850-1874	185	228.59	10.1	2000-	575	598.81
9	1875-1899	290	310.61				
a = 113050064 b = 2.0434 c = 672.5151 D = 0.9896							



Graphik: Wortschatzentwicklung der Elektrotechnik, Informationstechnik und Elektrophysik

Der gleiche Test wurde auch für die gesamte Entwicklungsphase ab dem 3. Jahrhundert vor Christus durchgeführt (vgl. Tabelle 1); das Testergebnis ist in diesem Fall mit D = 0.9930 sogar noch besser.

Ergebnis

Bisher konnte mit jeder derartigen Untersuchung die Hypothese, dass Sprachwandelprozesse gemäß dem Wachstumsgesetz verlaufen, gestützt werden. Mangels anderer Daten muss man die Wortschatzanteile, die die einschlägigen Wörterbücher mit Datierung anführen, als Stichproben aus dem Gesamtwortschatz betrachten, ohne dass man weiß, ob sie diese Bewertung tatsächlich verdienen. Die Ergebnisse sind aber immer wieder überzeugend, sowohl für den Gesamtwortschatz des Deutschen als auch für diejenigen Anteile, welche die Fremdwörter

einer bestimmten Herkunft betreffen (vgl. zuletzt Best 2006a), und für Fachwortschätze (Terminologie zu Computer und Elektrotechnik). Auch Verfallsprozesse entziehen sich dem nicht, wie Untersuchungen zum Untergang eines Teils des englischen Wortschatzes und in der deutschen Computersprache des Wortes „Elektronengehirn" zeigen (Best 2006b: 117f.); in diesen Fällen ändert sich lediglich das Vorzeichen für den Parameter *b* in Modell (1).

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Software

NLREG. Nonlinear Regression Analysis Program. Ph. H. Sherrod. Copyright (c) 1991–2001.

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On distributions of sentence lengths in Japanese writing

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Abstract. The lognormal distribution had long been thought to be the most appropriate probability distribution for Japanese sentence length distributions. Yet this view had been supported only by few researches with sparse sampling data and reasoning contradicting language reality. In order to show a more realistic approach, we analyzed a substantial number of samples. At first, 150 essays and short stories were drawn as a random sample, out of which any pieces of writing whose length was either less than 100 or more than 1000 sentences were excluded. As a result, 113 pieces remained as sample texts. We also paid attention to the kinds of sentences, separating those of dialogue from narrative ones. From each one of these 113 sample texts, three sentence length frequency distributions were acquired – the first one for a complete text, the second one for the collection of direct speech in the same text, and the third one for all the narrative parts excluding direct speech above. The results completely overturn the long-standing belief, proving that a lognormal distribution – which has been computed but will not be shown here – can never be well applied to Japanese sentence length distributions. Our new findings indicate that in place of this lognormal distribution, the Hyperpascal distribution maintains an excellent goodness of fit.

Keywords: Sentence length, Japanese, Hyperpascal distribution

1 Introduction

It has already been forty years since Yasumoto (1965, 1966) analyzed twenty sentences from each of 100 Japanese novels, judging that Japanese sentence lengths correspond either with a lognormal distribution or with a gamma distribution. Sasaki (1976) also examined 1500 sentences in total which were evenly extracted from three Japanese novels. The result was to corroborate Yasumoto's conclusion, with one of the three novels following a gamma distribution and the other two following a lognormal distribution. There is one more article in which Arai (2001) argues, with some of the literary works by Ryunosuke Akutagawa and Osamu Dazai as samples, that Japanese sentence lengths follow a lognormal distribution. In Europe and America, on the other hand, studies of the same kind have been conducted (Yule 1939; Williams 1940; Fucks 1968; Sichel 1974, 1975; Sigurd and Eeg-Olosson 2004; Kjetsaa 1978; Altmann 1988, 1992; Grotjahn and Altmann 1993; Niehaus 1997; Strehlow 1997; Wittek 1995; Kelih and Grzybek 2004, 2005; for more literature see http://lql.uni-trier.de). They have attempted to find models of sentence lengths in English, German, Chinese, Russian, Classical Greek, and Slovak, and used the negative binomial distribution, the Hyperpascal distribution, the Hyperpoisson distribution, a modified positive Poisson distribution, a compound Poisson distribution, and the lognormal distribution respectively. On the basis of this preceding research, we have analyzed all the sentences of 113 works by thirty-six Japanese writers. The result of our investigation into Japanese sentence length distributions follows.

Before we present the data, some theoretical preliminaries should be reviewed. The lognormal distribution has been introduced into linguistics on physical grounds. Since in the nature many phenomena are normally distributed, the first researchers supposed the same

would hold for language. But "normality" contradicts the self-organisatory character of language, and in most cases also its self-regulatory character. The *speakers* try to render every entity as easy for them as possible (memory effort, coding effort, production effort, etc.). They try to adapt the language to their own needs. Hence everything must be skewed, deviating from "normality." It is the self-regulation (exerted by the *hearer*) that stops great deviations and "pulls" them back again, but never to the "normal" state, because language must develop. Thus non-normality is the natural state of any linguistic phenomenon. The first researchers realized this fact but in an attempt to maintain the connection to physics, they modified the normal distribution in a way which is very popular in many sciences: they performed a logarithmic transformation yielding a skew distribution which could hold for many different data. But so far, this has no linguistic foundation. Besides, in linguistics one tries to fit discrete distributions to discrete data, but this is no great problem because parallel discrete and continuous distributions can be converted into one another (cf. for instance, Mačutek and Altmann 2007). We see the same endeavor with the gamma distribution, which represents a sum of squared normal distributions. This is, however, a special case of Pearson's Type III distribution.

A slightly better way is to consider sentence length to be arising from a Poisson process with a constant coefficient leading to the Poisson distribution, regarding the coefficient *a posteriori* as a variable. However, the last step is not completely arbitrary. Sichel considered the parameter of the Poisson distribution to be following a generalized inverse Gaussian distribution (containing a very flexible Bessel function) but never gave reasons for this decision. It is more realistic to use a very simple distribution, namely the gamma distribution – remembering the skewed normality – and obtain

$$\text{Poisson d. } (\lambda) \bigwedge_{\lambda} \text{ gamma d. } (k, q/p)$$

yielding the usual negative binomial distribution, which is an acceptable result because it can be substantiated in different ways.

In this study we shall try to apply the synergetic way of modelling sentence length.

2 Sample Texts and Analytical Methods

2.1 A measurement unit of sentence lengths

In present-day Japanese, what is called "kuten" is usually used to mark the end of a sentence, in the same way as a full stop or period in English. This "kuten," or the Japanese equivalent of a period, can be omitted in dialogue or in the written form of a conversation, where the second quotation mark of a pair is to terminate a sentence. This quotation mark is also used as a way of emphasizing a word, as with "kuten" in the first and second line of this paragraph. If we regard the word as the counting unit of sentence length, in languages using Latin or Cyrillic script, the analysis is much easier than in Japanese, because in these languages the word is separated from the next one by a single space. One can easily extract the number of words in a sentence, and the number thus obtained is directly equal to the length of that sentence. Japanese, on the other hand, uses two syllabic and one logographic script, in which words are never separated by whitespace within a sentence, and several individual morphemes are intricately linked with strict rules. In this case, the morpheme (instead of the word) could be regarded as a secondary unit of sentence length, and a sentence should be resolved into morphemes in the first place. One of the outstanding application programs for morphological

analysis of Japanese is "ChaSen."[1] Figure 1 illustrates how "ChaSen" morphemically analyzes a Japanese sentence, "Watashi-ha-sono-hon-wo-yonda," meaning *I have read the book*. The output consists of four columns, the first one on the left showing the exact forms of morphemes that appear on the paper, the next one showing their pronunciations in Roman letters, the third one showing the basic forms of their morphemes, and the last one showing what part of speech each morpheme belongs to. "ChaSen" enjoys high accuracy in its analysis, but it is not always wholly reliable and from the linguistic point of view it is a hybrid analysis. For instance, note that "sono" in fact consists of two morphemes from a diachronic viewpoint (cf. *sono, kono, ano* in which the morphemes can be separated in the same way as in German articles *d-er, d-ie, d-a*s); and "yonda" consists of the verb "yom(u)" and the past affix. But even if we accept the given analysis, sometimes it can provide false results. To make matters worse, Japanese has more compounds than many European languages. For example, Japanese equivalent of "lognormal distribution" is "taisu-seiki-bumpu." This compound consists of three words, "taisu" meaning "logarithm" or "log," "seiki," "normality," and "bumpu," "distribution." This compound, a little controversial, can be regarded either as one word representing one concept (cf. the German "Lognormalverteilung") or as three words (as in Slavic languages), or even as two, "taisu," "log" and "seiki-bumpu," "normal distribution." Incidentally, "ChaSen" treats this compound as three words.

私	watashi	私	noun (I)
は	ha	は	particle
その	sono	その	definite article (the)
本	hon	本	noun (book)
を	wo	を	particle
読ん	yom	読む	verb (read)
だ	da	だ	aux. verb (have)

Figure 1. The output of ChaSen's morphemic analysis: "I have read the book"

We are aware that the length of a linguistic unit should be measured in terms of the number of its immediate constituents, in our case, clauses. But for Japanese there are no programs of this kind and computational linguists do not care for this aspect of sentence structure. Thus the complete analysis of all texts must be done with pencil and paper. On understandable grounds we shall evade such a procedure. The other way to get the length of a Japanese sentence mechanically is to count up the number of characters, or letters, instead of morphemes, using a character as the minimum constituent of a sentence. In this way, we can avoid the possible mistakes and ambiguities of a morphemic analysis. Naturally enough, previous studies have adopted the number of characters in their analyses. Here we must take note of the fact that even this approach has two problematic aspects. One is that a Japanese character can be either an independent morpheme in itself, or a mere mora as in most cases. The second one is that Japanese has three different writing systems, *hiragana*, *katakana*, and *kanji*. An English word, "horse," can be written in three ways. In Figure 2, all three symbols adjacent to "horse" have the same pronunciation, "uma," conveying the same concept of "horse." The first two forms of the *kana* writing system have the same number of characters, but the third one has only one character. These equivalents for "horse" which are to be differently distributed might appear

[1] http://chasen.naist.jp/hiki/ChaSen/

in one and the same Japanese sentence. Sentence length should be a fixed (invariant) quantity. In this sense, the fact that a choice of a writing system would possibly have a significant influence on the sentence length distribution simply casts doubts on the validity of the character as a counting unit. There is one more possibility to be taken into consideration: the phoneme. But phonemes are not immediate constituents of sentence and the support of the random variable "length" would contain so many values that many of them would have the frequency zero. This automatically leads to a senseless multimodal distribution having no relevance to the analysis.

horse うま ウマ 馬

Figure 2. The three ways of writing "horse" in Japanese

In collecting data on Japanese sentence lengths, there is one further question other than the selection of a measurement unit: It is the question of whether dialogue can be analyzed in the exactly same way as narrative. Mizutani (1957) pointed out that both description and dialogue in literary works have their own distributions and parameters, for example, the former following a normal distribution, and the latter, a gamma distribution. This is, however, Mizutani's mere speculation, not verified by any further experiments and, as said above, the first approximation of a kind.

Having taken into account all problematic elements, we have examined a considerable number of Japanese writers' works. This time we have relied upon "ChaSen" automatically measuring all the sentence lengths of each entire text, and the number of each-sentence morphemes resulting from its analysis has been employed without any alteration. Using the theoretical approaches of G.K. Zipf (1949) and his followers in later years, we conjectured that there should be a kind of self-regulation of sentence lengths connecting the neighbouring classes by a proportionality function (cf. Altmann and Köhler 1996), i.e.

(1) $$P_x = g(x)P_{x-1}$$

Here $g(x) = f(x)/h(x)$. Now, $f(x)$ can be interpreted as the (diversification) force of the speaker, his subconscious endeavour to make his speech production as easy as possible. However, taken to an extreme, this would destroy any communication. Thus this self-organizing force must be controlled by the hearer (or the community), by a self-regulating function $h(x)$. Both must be constructed in such a way that the probability distribution converges. In a simple and very general case we let $f(x) = a + bx$ and $h(x) = c + dx$. Inserting them in (1) we obtain

(2) $$P_x = \frac{f(x)}{h(x)}P_{x-1} = \frac{a+bx}{c+dx}P_{x-1} = \frac{(a/b+x)}{(c/d+x)}\frac{b}{d}P_{x-1}.$$

Replacing $a/b = k$-1, $c/d = m$-1 and $b/d = q$ ($0 < q < 1$) we obtain (k and m must fulfil some special conditions)

(3) $$P_x = \frac{k+x-1}{m+x-1}qP_{x-1} \quad .$$

Solving this simple difference equation we obtain the Hyperpascal distribution

$$(4) \qquad P_x = \frac{\binom{k+x-1}{x}}{\binom{m+x-1}{x}} q^x P_0, \quad x = 0,1,2,\ldots$$

where $P_0^{-1} = {}_2F_1(k,1;m,q)$ and $F(.)$ is the hypergeometric function. It has been shown (cf. Altmann 1988) that this distribution is adequate if sentence length is not measured in terms of the number of immediate constituents, whereas in terms of that of clauses, the negative binomial is adequate. The Hyperpascal distribution builds a family, some members of which (Poisson, geometric, Katz family, shifted logarithmic, Hyperpoisson, Waring, Yule etc.) are employed in different domains of linguistics. And it is interesting to see that its continuous counterpart is Pearson's Type III distribution, i.e. the generalized gamma distribution (cf. Mačutek and Altmann 2007). Thus using special kinds of gamma distribution is a continuous approximation to the solution of the problem. In both cases (discrete or continuous), we must perform an *a priori* pooling of classes for shorter texts because many classes are represented very insufficiently. Pearson Type III would require numerical integration with optimization, while a ready made software will be available, if one decides to work with the Hyperpascal.

Consider the data "aitobi3 [Osamu Dazai's Ai to Bi nitsuite]" presented in Table 1.

Table 1
The raw data of the file "aitobi3"

X	f(X)	X	f(X)	X	f(X)	X	f(X)
1	1	26	1	51	0	76	0
2	0	27	0	52	0	77	0
3	8	28	4	53	1	78	0
4	9	29	1	54	0	79	0
5	3	30	1	55	0	80	0
6	21	31	1	56	1	81	0
7	10	32	4	57	0	82	0
8	14	33	1	58	0	83	0
9	6	34	1	59	0	84	0
10	7	35	0	60	0	85	0
11	8	36	0	61	0	86	0
12	6	37	0	62	0	87	0
13	5	38	0	63	0	88	0
14	6	39	1	64	0	89	0
15	6	40	0	65	0	90	0
16	3	41	1	66	1	91	0
17	5	42	1	67	0	92	0
18	1	43	1	68	0	93	0
19	3	44	0	69	0	94	0
20	1	45	0	70	0	95	0
21	0	46	0	71	0	96	0
22	3	47	1	72	0	97	0
23	1	48	0	73	0	98	0
24	6	49	0	74	0	99	0
25	0	50	0	75	0	100	1

As can be seen, the individual classes are not sufficiently occupied, thus a number of modes are present and the fitting of any discrete distribution would be rather a very raw approximation. The data is presented graphically in Figure 3. In a situation like this, one usually pools some classes in order to obtain expected values at least greater than 1. This can be done either before or after applying a theoretical distribution. We shall do it before the analysis. We first choose an interval of three values, i.e. pool the classes 1-2-3, 4-5-6, 7-8-9, …and let the class be represented by its mean, i.e. X = 2, 5, 8, 11, 14,…. Then we define a new variable, x = (X – 2)/3 whose support is x = 0,1,2,3,…. Filling the frequency values in the given intervals, we obtain a smoothed distribution presented in Table 2. The expected values of the Hyperpascal distribution are shown in the third column of Table 2 and a graphic picture of the fit is shown in Figure 4. It can be inferred that greater smoothing intervals would lead to a still better fitting.

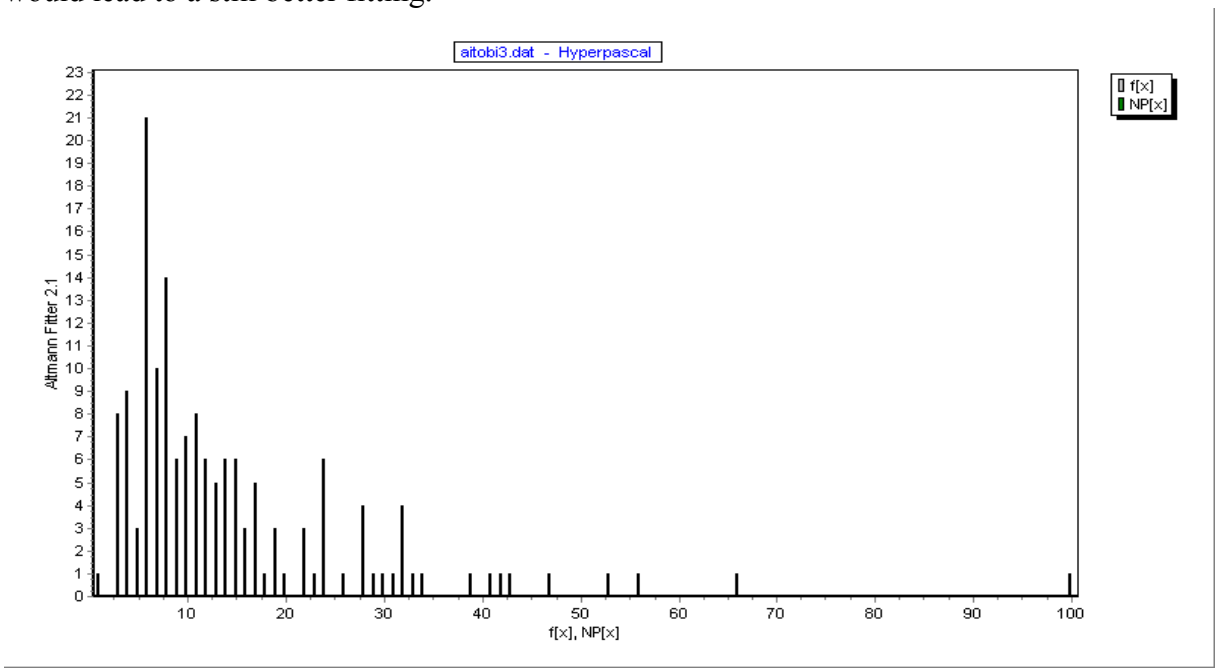

Figure 3. Raw data of sentence lengths in the file „aitobi3 [Ai to Bi nitsuite]“

Table 2
Smoothed data and the theoretical values

x	f(x)	NP(x)	x	f(x)	NP(x)	x	f(x)	NP(x)
0	9	8.48	12	1	2.09	24	0	0.08
1	33	29.86	13	2	1.60	25	0	0.06
2	30	25.94	14	1	1.22	26	0	0.05
3	21	21.07	15	1	0.93	27	0	0.03
4	17	16.71	16	0	0.71	28	0	0.03
5	9	13.09	17	1	0.54	29	0	0.02
6	7	10.17	18	1	0.41	30	0	0.02
7	10	7.87	19	0	0.31	31	0	0.01
8	1	6.06	20	0	0.24	32	0	0.01
9	6	4.66	21	0	0.18	33	1	0.03
10	6	3.57	22	1	0.14			
11	1	2.74	23	0	0.10			
k = 0.2026, m = 0.0434, q = 0.7536, X^2 = 12.35, DF = 13, P = 0.50								

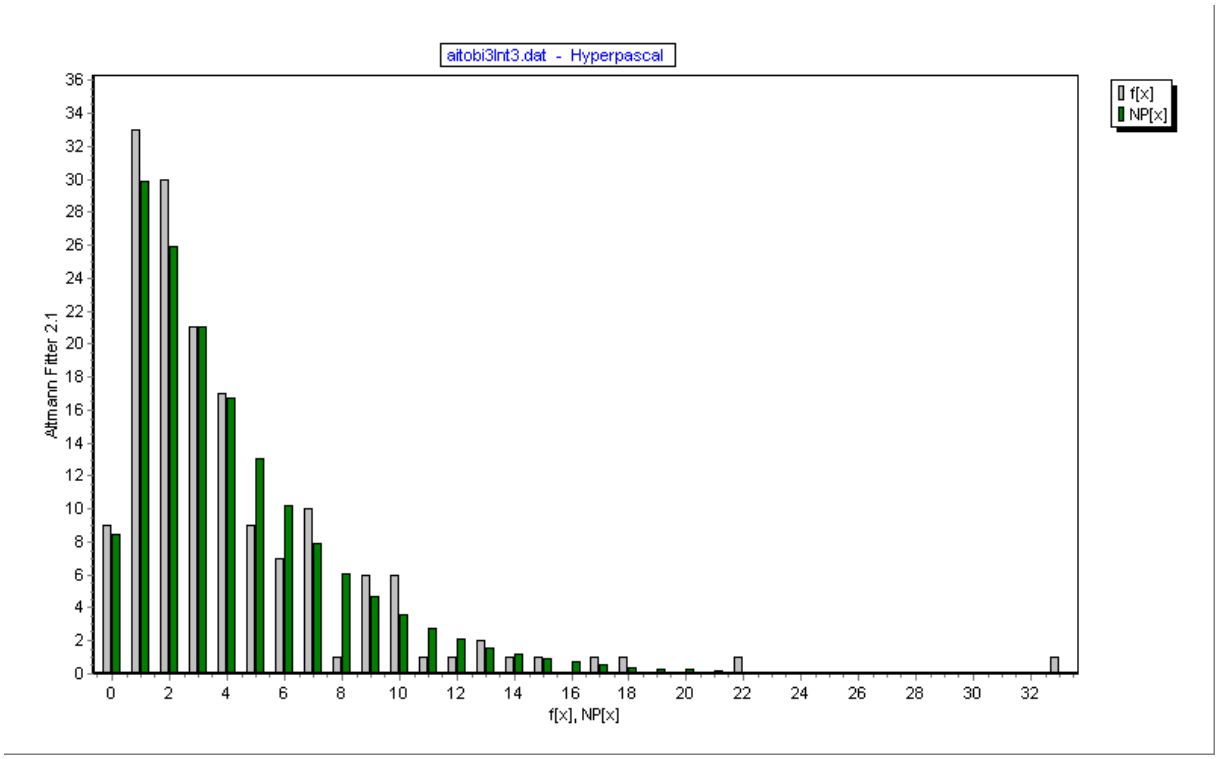

Figure 4. Fitting the Hyperpascal to smoothed data

The results of fitting the Hyperpascal to all data analysed in morphemes are presented in Table 3. We preferred three kinds of intervals: 3, 5, and 7, though using other ones perhaps a still better fitting could be achieved. Actually we tried 9 and 11 besides, in a few particular cases of either direct speech or narrative as we shall see later in Table 4 and 5. But our aim was not to show exactly how a given text must be prepared in order to obtain a perfect fit. Rather we try to show that Japanese sentence lengths measured in the traditional way accord with Sherman's law resulting in the Hyperpascal distribution (Altmann 1988). The significance level has been fixed at $\alpha = 0.01$.

Table 3
Fitting the Hyperpascal to sentence lengths measured morphemically: complete texts (Intervals 3, 5, 7) (FF – fitting failed)

Writer	Text	Size	K	M	Q	DF	X^2	Prob	Interval
akutagawa	giwaku	276	0.1035	0.0567	0.8013	18	31.75	0.02	5
akutagawa	jigokuhen	526	0.6193	0.1744	0.8656	34	50.86	0.03	3
akutagawa	kaikano	298	FF						
akutagawa	kage	333	FF						
akutagawa	kataki	285	9.4345	2.9191	0.5083	15	18.28	0.25	3
akutagawa	kuranosuke	218	7.5058	1.1591	0.3611	9	5.13	0.82	5
akutagawa	oritsuto	965	2.8834	0.8834	0.4260	9	12.74	0.17	5
akutagawa	rashom	160	FF						
akutagawa	umano	374	1.8397	0.2441	0.4299	7	16.33	0.02	5
ango	ishino	322	0.1787	0.0515	0.7347	13	14.75	0.32	7
arishima	chiisaki	300	2.6558	0.7654	0.6784	18	20.73	0.29	3
arishima	hitofusano	177	1.3649	0.3644	0.6086	10	8.18	0.61	5

arishima	kajito	307	0.1623	0.0467	0.6583	10	5.11	0.88	5
arishima	oyako	560	1.3034	0.2893	0.6048	13	10.16	0.68	5
arishima	kankan	303	1.7041	0.4752	0.6154	13	11.81	0.54	5
dazai	aitobi	454	0.5679	0.4472	0.5542	7	13.56	0.06	7
dazai	joseito	988	0.2281	0.1188	0.8016	25	39.86	0.03	3
dazai	kamome	460	0.0384	0.0223	0.5159	6	8.61	0.20	7
dazai	kirigirisu	301	0.3302	0.0738	0.7120	14	12.03	0.60	5
dazai	kotenfu	444	0.3418	0.1386	0.7251	15	27.93	0.02	3
dazai	merosu	471	0.1721	0.0532	0.5046	6	3.59	0.73	5
dazai	oto	159	0.8497	0.5280	0.7471	13	17.81	0.17	3
dazai	sado	560	0.1395	0.0489	0.5015	6	9.99	0.13	5
dazai	ubasute	608	FF						
dazai	osan	212	FF						
dazai	kashoku	696	FF						
hashimoto	chizu	378	1.0635	0.03384	0.5919	10	13.48	0.20	7
hirabayashi	yamabuki	437	0.9106	0.3076	0.6612	14	5.86	0.97	5
hojo	gantai	192	2.2442	1.0185	0.6434	12	7.80	0.80	5
hori	seikazoku	435	1.1506	0.3388	0.7521	21	34.53	0.03	3
hori	tabino	225	0.2257	0.0668	0.7530	15	15.73	0.40	7
hori	hanao	382	FF						
hori	banka	312	1.6980	0.6295	0.6597	14	16.00	0.31	5
hori	hono	242	0.2175	0.0609	0.8409	21	17.89	0.66	5
itakura	goshiki	568	1.7728	0.3777	0.5854	13	14.76	0.32	3
itakura	haruno	217	6.9692	0.6865	0.2053	4	1.55	0.82	5
itakura	yamato	331	0.5303	0.1434	0.6014	9	12.33	0.20	5
ito	hamagiku	342	2.1256	0.3238	0.4731	9	4.02	0.91	5
ito	koroku	281	2.0073	0.3486	0.6579	16	13.87	0.61	3
ito	kyonen	466	FF						
ito	nanako	283	1.3859	0.1809	0.5288	9	3.91	0.92	5
ito	nogiku	975	0.5316	0.1260	0.5578	10	8.10	0.62	7
kajii	deinei	242	2.3732	0.4015	0.4458	7	8.77	0.27	5
kajii	fuyuhae	330	2.3847	0.5663	0.6403	16	12.28	0.72	5
kajii	koubi	193	11.9507	1.4538	0.2232	6	13.27	0.04	5
kajii	remon	142	0.6119	0.0727	0.7874	17	19.75	0.29	3
kajii	setsugo	277	0.2736	0.1301	0.7295	14	17.01	0.26	3
katai	ippei	511	1.9371	0.4552	0.3933	6	4.96	0.55	5
katai	shojo	266	0.4783	0.2250	0.7607	16	9.71	0.88	5
katai	tokoyo	635	0.8703	0.2359	0.7332	20	18.55	0.55	3
kikuchi	emu	268	2.6557	1.0129	0.4489	6	2.97	0.81	7
kikuchi	seni	297	5.1167	0.3295	0.2304	5	6.65	0.25	7
kikuchi	shimabara	404	0.0394	0.0204	0.7450	15	18.34	0.25	5
kikuchi	shusse	228	0.9690	0.1952	0.5241	7	6.24	0.51	7
kikuchi	wakasugi	221	17.7068	1.0198	0.1526	6	5.30	0.51	7
koda	shonen	114	0.1233	0.0110	0.8329	17	20.18	0.27	5
kuroshima	ana	435	2.0282	0.5573	0.6166	14	14.24	0.43	3
kuroshima	dempo	216	0.5852	0.2358	0.6399	10	9.13	0.52	5
kuroshima	mogura	654	4.3585	0.7056	0.3205	7	13.70	0.06	5
kuroshima	mon	166	0.9769	0.1241	0.3403	3	3.79	0.28	7

kuroshima	nusumu	364	2.7890	0.3142	0.2367	3	1.11	0.77	7
kuroshima	sato	167	0.3650	0.1321	0.5824	7	1.68	0.98	5
kuroshima	tongun	252	1.6990	0.2883	0.4819	8	9.23	0.32	5
kuroshima	zensho	316	1.9027	0.5389	0.3649	5	1.99	0.85	7
makino	tsurube	361	FF						
makino	kinada	279	1.7881	0.7121	0.6357	12	10.28	0.59	7
minakami	yamanote	387	0.5858	0.3683	0.7696	18	13.90	0.74	5
mishima	hashi	359	0.8802	0.3009	0.5449	8	8.83	0.36	7
miyamoto	akarui	297	1.6922	1.3023	0.7606	17	28.31	0.04	3
miyazawa	karasu	165	0.2216	0.1312	0.7984	16	18.01	0.32	3
murai	sobano	179	1.6458	0.1299	0.7071	18	33.89	0.01	5
oda	osaka	164	0.2717	0.0734	0.7978	16	29.21	0.02	5
oda	keiba	231	0.1659	0.0387	0.7543	15	24.77	0.05	7
ogai	futarino	412	34.5950	1.1263	0.0548	4	8.57	0.07	7
ogai	asobi	373	2.9731	0.4692	0.2801	4	1.77	0.78	7
ogai	shokudo	193	53.72	4.3131	0.0817	5	5.05	0.41	7
ogai	niwatori	762	6.6721	1.1193	0.1941	4	4.07	0.40	7
ogai	kazui	271	0.4945	0.1427	0.5723	8	6.69	0.57	7
okamoto	karei	286	1.1520	0.3446	0.7406	18	12.74	0.81	3
okamoto	kingyo	830	1.5109	0.6276	0.5896	12	20.43	0.06	7
okamoto	rigyo	171	0.6448	0.2775	0.7991	19	19.11	0.45	3
okamoto	sushi	366	0.8861	0.2568	0.6546	13	14.82	0.32	5
okamoto	tokaido	378	0.0820	0.0438	0.6949	12	11.01	0.53	7
sasa	kikansha	217	20.0666	0.5214	0.0542	2	0.73	0.70	7
sasa	midori	127	1.3497	0.3012	0.6031	10	12.79	0.24	5
shimazaki	shishu	316	0.8158	0.1699	0.7545	20	21.55	0.37	3
shimazaki	namiki	373	0.2725	0.0881	0.6094	9	6.85	0.65	5
shimazaki	fune	354	2.9653	0.5659	0.4660	9	12.08	0.21	5
shimazaki	mebae	881	2.1641	0.4502	0.4824	9	3.56	0.94	5
shimazaki	bumpai	497	0.8753	0.3177	0.5588	9	7.76	0.56	7
shiraki	saite	236	0.6287	0.1199	0.7862	20	23.21	0.28	3
soseki	buncho	411	0.8648	0.0818	0.4942	8	4.31	0.83	5
soseki	hennaoto	110	0.0692	0.0158	0.7292	10	6.76	0.75	5
soseki	sakubutsu	183	0.0463	0.0070	0.7325	12	6.37	0.90	5
soseki	kotonone	776	1.2049	0.3660	0.4216	7	1.96	0.96	7
soseki	tegami	263	0.6802	0.2308	0.6347	10	10.31	0.41	7
suzu	ogon	439	20.3908	1.7829	0.1431	6	11.73	0.07	5
takiji	haha	294	0.2951	0.1829	0.7342	14	10.90	0.69	5
takiji	yukino	739	19.5497	8.2619	0.3997	12	9.88	0.63	3
unno	daino	489	0.9564	0.2851	0.5884	10	10.41	0.41	5
unno	kagaku	114	0.6669	0.1175	0.5556	6	1.81	0.94	7
unno	kibutsu	466	1.2499	0.4762	0.4860	7	7.58	0.37	7
unno	neon	408	1.1334	0.4731	0.5099	7	9.91	0.19	7
unno	tsuki	505	0.0921	0.0394	0.8025	22	28.00	0.18	3
watanabe	uso	300	0.2824	0.1313	0.6904	12	7.11	0.85	5
watanabe	akai	197	2.0690	0.5612	0.5421	9	7.80	0.55	5
watanabe	aruhaha	193	2.8232	1.0305	0.4449	6	9.30	0.16	7
watanabe	shohai	298	0.5499	0.1965	0.6890	12	9.22	0.68	5

yamada	musashino	351	0.3253	0.1736	0.8413	26	21.01	0.74	3
yamashita	ruten	116	1.2913	0.0707	0.6484	12	16.08	0.19	5
yokomitsu	kikaiy	244	FF						
yokomitsu	jikan	150	3.6477	0.6335	0.6743	18	19.59	0.36	7
yumeno	koko	439	1.3923	0.4764	0.6191	12	14.53	0.27	5

As can be seen, out of 113 texts 103 could be captured by the Hyperpascal. Even the residual 10 data could be captured if we attempted a different priori pooling, but this is no more than a question of principle. Sometimes we even left smaller intervals if the fitting was significant. We did not try to achieve "the best fit." We rather scrutinize the problem of distinguishing between dialogue and narrative parts. Table 4 contains the same texts, showing the result of direct speech, and followed by Table 5 showing that of narrative. However, there is a problem associated with direct speech. If it is dialogue, i.e. if there are at least two speaking persons, the author must differentiate them in some way, for example, in their sentence length. Hence dialogue has two independent parts which must not be mixed. If there are *more* speaking persons, then each speaker's words must be evaluated separately. This kind of research might be of great interest and use for the purposes of analyzing a single work from a literary point of view. For our particular purposes, namely for corroborating a variant of Sherman's law, it would play a merely subordinate role. The results of dialogue and narrative parts are given below consecutively. In respect of direct speech, there are a dozen texts that contain no dialogue data (ND) and as many texts that do not have enough data to fit the Hyperpascal (NED), and there are four texts where the fitting failed (FF).

Table 4
Direct speech (Intervals 3, 5, 7, 9, 11)

Writer	Text	Size	K	M	Q	DF	X^2	P	Interv.
akutagawa	giwaku	44	FF						
akutagawa	jigokuhen	114	0.1816	0.1033	0.4837	4	1.27	0.87	7
akutagawa	kage	116	0.1826	0.1846	0.5044	3	2.25	0.52	7
akutagawa	kaikano	188	20.2672	3.6874	0.2500	9	15.87	0.07	9
akutagawa	kataki	36	6.2749	0.4248	0.1614	2	0.40	0.82	5
akutagawa	kuranosuke	79	22.9651	1.448374	0.1061	3	0.47	0.93	7
akutagawa	oritsuto	462	0.2653	0.121514	0.3137	2	2.09	0.35	7
akutagawa	rashom	26	1.3298	0.393276	0.5471	4	5.08	0.28	5
akutagawa	umano	132	0.1818	0.049125	0.4942	4	10.92	0.03	5
ango	ishino	NED							
arishima	chiisaki	NED							
arishima	hitofusano	35	FF						
arishima	kajito	53	2.2645	1.3530	0.3170	1	0.30	0.59	7
arishima	kankan	37	1.5100	1.2894	0.6497	5	5.14	0.40	5
arishima	oyako	199	0.4421	0.2238	0.5669	6	2.07	0.91	7
dazai	aitobi	298	0.4143	0.3265	0.6619	10	12.99	0.22	5
dazai	joseito	58	2.5983	1.8394	0.5290	4	3.86	0.43	3
dazai	kamome	122	1.1527	1.2311	0.5092	3	4.83	0.18	7
dazai	kashoku	209	0.1433	0.0780	0.4593	4	9.23	0.06	5
dazai	kirigirisu	NED							
dazai	kotenfu	187	0.2690	0.1160	0.7351	13	18.14	0.15	3
dazai	merosu	168	0.4932	0.1373	0.3484	3	0.77	0.86	5

dazai	osan	96	1.7210	3.2101	0.5548	1	2.95	0.086	9
dazai	oto	38	0.7478	0.7053	0.6608	4	5.18	0.27	3
dazai	sado	102	1.1612	1.2352	0.4033	1	0.76	0.38	7
dazai	ubasute	208	0.0723	0.0428	0.6776	10	14.39	0.16	3
hashimoto	chizu	117	4.1328	1.9360	0.5181	7	4.30	0.75	5
hirabayashi	yamabuki	184	1.1526	0.5655	0.5887	8	1.03	0.998	5
hojo	gantai	39	0.6168	0.4457	0.5251	3	1.52	0.68	5
hori	banka	54	3.1609	0.9597	0.2349	1	0.13	0.72	7
hori	hanao	31	0.3769	0.1168	0.6588	6	5.96	0.43	3
hori	hono	152	1.5339	0.7042	0.7066	13	9.58	0.73	7
hori	seikazoku	57	1.7604	0.4201	0.4760	5	2.21	0.82	3
hori	tabino	NED							
itakura	goshiki	NED							
itakura	haruno	NED							
itakura	yamato	NED							
ito	hamagiku	84	1.5591	0.3012	0.4500	5	3.24	0.66	5
ito	koroku	111	0.0454	0.0180	0.4796	3	1.60	0.66	7
ito	kyonen	35	0.7758	0.1511	0.4300	2	0.75	0.69	5
ito	nanako	29	15.9699	1.2484	0.1563	3	1.16	0.76	3
ito	nogiku	393	0.1374	0.0317	0.6467	10	18.21	0.05	5
kajii	deinei	ND							
kajii	fuyuhae	ND							
kajii	koubi	ND							
kajii	remon	ND							
kajii	setsugo	ND							
katai	ippei	95	0.5172	0.1831	0.4502	3	5.89	0.12	3
katai	shojo	57	0.1548	0.0763	0.6293	5	1.62	0.90	5
katai	tokoyo	192	0.3829	0.1211	0.6609	10	10.72	0.38	3
kikuchi	emu	83	0.3832	0.1026	0.4789	3	2.715	0.44	5
kikuchi	seni	85	1.715	0.2063	0.1747	1	1.29	0.26	11
kikuchi	shimabara	214	0.3771	0.1867	0.5792	7	12.26	0.09	5
kikuchi	shusse	34	0.0994	0.0165	0.4302	2	0.34	0.84	5
kikuchi	wakasugi	11	FF						
koda	shonen	ND							
kuroshima	ana	108	0.4544	0.1806	0.3687	1	4.18	0.04	5
kuroshima	dempo	80	0.6002	0.5297	0.6574	6	5.59	0.47	5
kuroshima	mogura	153	38.946	9.1844	0.2144	7	2.38	0.94	3
kuroshima	mon	62	0.1098	0.0206	0.5401	3	5.23	0.16	5
kuroshima	nusumu	96	0.1706	0.1061	0.6348	6	12.08	0.06	3
kuroshima	sato	68	0.2488	0.0922	0.6740	6	14.66	0.02	3
kuroshima	tongun	61	1.4061	0.2862	0.2784	1	0.96	0.33	5
kuroshima	zensho	74	2.3327	2.6170	0.7587	8	3.02	0.93	3
makino	kinada	89	0.5892	0.1421	0.7448	12	14.78	0.25	3
makino	tsurube	157	1.5685	1.3012	0.5458	5	7.30	0.20	7
minakami	yamanote	102	0.1527	0.0598	0.2744	1	0.40	0.53	7
mishima	hashi	74	0.3204	0.1001	0.3467	1	4.76	0.03	5
miyamoto	akarui	113	1.7018	1.5909	0.6519	6	2.97	0.81	3
miyazawa	karasu	62	0.4617	0.2967	0.5867	4	2.86	0.58	3

murai	sobano	ND							
oda	keiba	NED							
oda	osaka	NED							
ogai	asobi	65	4.1224	5.8304	0.7282	3	6.05	0.11	5
ogai	futarino	56	1.7175	1.4188	0.6062	4	4.63	0.33	5
ogai	kazui	65	0.2298	0.1528	0.5261	3	3.02	0.39	5
ogai	niwatori	175	0.9699	1.0521	0.4804	3	8.79	0.03	7
ogai	shokudo	102	1.6770	0.5108	0.4607	5	3.40	0.64	7
okamoto	karei	92	0.0462	0.0101	0.7534	10	8.29	0.60	3
okamoto	kingyo	198	0.0338	0.0243	0.7854	13	22.56	0.05	3
okamoto	rigyo	52	2.0128	1.6204	0.5564	2	3.00	0.22	5
okamoto	sushi	78	0.3798	0.1484	0.4783	3	5.49	0.14	5
okamoto	tokaido	102	0.0672	0.0225	0.8015	14	7.20	0.93	3
sasa	kikansha	102	FF						
sasa	midori	53	3.3945	0.7119	0.3239	3	0.74	0.86	7
shimazaki	bumpai	120	1.6281	0.2471	0.2613	2	1.54	0.46	5
shimazaki	fune	34	0.3927	0.1668	0.5610	3	2.87	0.41	5
shimazaki	mebae	142	1.4990	0.8369	0.6176	8	11.57	0.17	3
shimazaki	namiki	156	0.4712	0.1523	0.4678	5	4.20	0.52	5
shimazaki	shishu	33	2.9693	0.5955	0.3710	3	1.93	0.59	5
shiraki	saite	38	0.3329	0.0478	0.5619	4	4.63	0.33	3
soseki	buncho	NED							7
soseki	hennaoto	28	0.3773	0.2522	0.5495	2	0.56	0.76	5
soseki	kotonone	375	0.0813	0.0264	0.6194	9	3.38	0.95	5
soseki	sakubutsu	ND							7
soseki	tegami	52	35.634	2.1977	0.0910	4	3.59	0.46	3
suzu	ogon	115	2.4353	0.1166	0.2720	3	1.84	0.61	5
takiji	haha	83	0.6368	0.3612	0.6280	6	10.18	0.12	5
takiji	yukino	174	0.6376	0.5780	0.4857	4	4.2	0.38	3
unno	daino	200	0.8300	0.3943	0.5754	7	2.3	0.94	5
unno	kagaku	NED							7
unno	kibutsu	216	1.3625	1.0254	0.7349	14	9.89	0.77	3
unno	neon	226	0.2116	0.1524	0.6677	9	4.54	0.87	5
unno	tsuki	245	0.1203	0.0556	0.6774	10	6.17	0.80	3
watanabe	akai	NED							
watanabe	aruhaha	ND							
watanabe	shohai	ND							
watanabe	uso	164	0.6077	0.5130	0.5353	5	3.28	0.66	7
yamada	musashino	185	0.4815	0.5999	0.6410	6	5.24	0.51	7
yamashita	ruten	90	3.2763	0.3158	0.3972	6	7.10	0.31	7
yokomitsu	jikan	ND							
yokomitsu	kikaiy	ND							
yumeno	koko	137	0.3294	0.2449	0.8120	16	16.59	0.41	3

Table 5
Narrative (Intervals 3, 5, 7, 9, 11)

Writer	Text	Size	K	M	Q	DF	X^2	P	
akutagawa	giwaku	232	3.2508	0.7474	0.4755	9	11.81	0.22	7
akutagawa	jigokuhen	412	1.7096	0.3189	0.6290	13	26.62	0.01	7
akutagawa	kage	217	12.0019	0.8216	0.2260	7	11.47	0.12	5
akutagawa	kaikano	110	1.4427	0.2013	0.5610	7	9.97	0.19	7
akutagawa	kataki	249	527.7755	1.9709	0.0087	7	13.24	0.07	5
akutagawa	kuranosuke	139	5.9010	0.3954	0.3701	9	2.28	0.99	5
akutagawa	oritsuto	503	FF						
akutagawa	rashom	134	FF						
akutagawa	umano	242	11.2705	0.2983	0.15839	5	7.36	0.20	5
ango	ishino	318	0.1412	0.0388	0.7412	13	14.82	0.32	7
arishima	chiisaki	297	3.9009	1.1110	0.6215	17	18.79	0.34	3
arishima	hitofusano	142	2.0363	0.2829	0.5584	10	4.81	0.90	5
arishima	kajito	254	0.5221	0.1362	0.5169	6	3.56	0.74	7
arishima	kankan	266	0.3565	0.0729	0.6264	9	6.06	0.73	7
arishima	oyako	361	4.0829	0.9981	0.6000	17	9.78	0.91	3
dazai	aitobi	156	0.5603	0.3690	0.5256	5	4.85	0.43	7
dazai	joseito	930	0.2664	0.1216	0.8011	25	38.53	0.04	3
dazai	kamome	338	0.1819	0.0760	0.4907	5	7.05	0.22	7
dazai	kashoku	487	0.0963	0.0275	0.6607	11	17.94	0.08	5
dazai	kirigirisu	299	0.3799	0.0815	0.7082	14	12.30	0.58	5
dazai	kotenfu	257	0.4089	0.1571	0.6982	12	14.66	0.26	3
dazai	merosu	303	0.3224	0.0806	0.5184	6	4.00	0.68	5
dazai	osan	116	0.3899	0.1703	0.8125	17	33.73	0.01	7
dazai	oto	121	0.2934	0.1345	0.5840	6	8.65	0.19	7
dazai	sado	458	0.2872	0.0790	0.4953	6	11.47	0.07	5
dazai	ubasute	400	0.4038	0.2527	0.4846	5	14.88	0.01	7
hashimoto	chizu	261	0.6289	0.1289	0.6293	10	11.99	0.29	7
hirabayashi	yamabuki	253	0.8716	0.0803	0.6629	13	5.46	0.96	5
hojo	gantai	153	2.0267	0.2963	0.5915	11	7.67	0.74	5
hori	banka	258	6.6566	2.5129	0.6290	19	14.07	0.78	3
hori	hanao	351	1.1630	0.1029	0.8032	29	35.43	0.19	3
hori	hono	90	0.1972	0.0369	0.8306	17	14.45	0.63	5
hori	seikazoku	378	1.7554	0.3774	0.7199	20	35.53	0.02	3
hori	tabino	217	0.2795	0.0572	0.7479	15	16.16	0.37	7
itakura	goshiki	532	0.5177	0.0946	0.3713	4	3.66	0.45	7
itakura	haruno	214	9.7424	0.7743	0.1661	4	1.47	0.83	5
itakura	yamato	309	0.6158	0.1083	0.5859	9	11.63	0.23	5
ito	hamagiku	258	2.5754	0.3032	0.4484	8	2.97	0.94	5
ito	koroku	170	1.5610	0.0512	0.4003	6	3.13	0.79	7
ito	kyonen	431	1.6990	0.1969	0.3002	4	9.27	0.05	9
ito	nanako	254	2.8372	0.2986	0.4302	8	7.76	0.46	5
ito	nogiku	582	1.8452	0.2851	0.4589	8	9.78	0.28	7
kajii	deinei	222	5.1011	0.4674	0.3167	7	10.22	0.18	5
kajii	fuyuhae	305	2.3021	0.3570	0.6201	15	9.47	0.85	3

kajii	koubi	187	3.7351	0.5448	0.3925	7	14.88	0.04	5
kajii	remon	134	1.360	0.1093	0.7077	15	18.87	0.22	3
kajii	setsugo	180	0.6015	0.1389	0.7129	13	16.01	0.25	3
katai	ippei	416	0.5105	0.0858	0.3799	4	3.87	0.42	7
katai	shojo	209	0.5526	0.1179	0.8481	27	22.16	0.73	3
katai	tokoyo	443	1.9931	0.2240	0.6600	18	13.79	0.74	3
kikuchi	emu	185	0.2209	0.0580	0.7372	9	13.21	0.15	5
kikuchi	seni	212	2.3085	0.1345	0.3451	5	4.99	0.42	7
kikuchi	shimabara	190	FF						
kikuchi	shusse	194	1.5669	0.1836	0.4743	7	6.802	0.45	7
kikuchi	wakasugi	210	FF						
koda	shonen	114	0.1233	0.0110	0.8329	17	20.18	0.27	5
kuroshima	ana	327	1.9025	0.2617	0.4512	8	4.22	0.84	5
kuroshima	dempo	136	1.8996	0.3230	0.6698	15	12.16	0.67	3
kuroshima	mogura	501	3.5743	0.2388	0.3218	7	12.05	0.10	5
kuroshima	mon	104	1.5992	0.1087	0.3088	3	3.06	0.38	7
kuroshima	nusumu	268	4.0326	0.2841	0.4515	11	8.64	0.66	3
kuroshima	sato	99	0.0074	0.0010	0.5192	4	1.76	0.78	7
kuroshima	tongun	191	2.4103	0.1772	0.4365	8	8.02	0.43	5
kuroshima	zensho	242	1.9764	0.1880	0.4369	7	3.49	0.84	5
makino	kinada	190	1.3305	0.5076	0.7135	12	21.60	0.04	7
makino	tsurube	204	0.5034	0.2017	0.5960	8	13.21	0.11	9
minakami	yamanote	285	3.1271	0.6449	0.4968	10	15.85	0.10	7
mishima	hashi	285	0.9655	0.1537	0.6460	12	10.05	0.61	5
miyamoto	akarui	184	11.9772	1.3814	0.1700	4	8.57	0.07	7
miyazawa	karasu	103	0.0022	0.0014	0.8347	17	28.06	0.04	3
murai	sobano	179	1.6458	0.1299	0.7071	18	33.89	0.01	5
oda	keiba	228	0.1002	0.0215	0.7602	15	25.33	0.05	7
oda	osaka	162	0.2893	0.0806	0.7980	16	28.82	0.03	5
ogai	asobi	308	3.2854	0.3025	0.2594	4	1.79	0.77	7
ogai	futarino	356	6.6858	1.4855	0.4836	14	12.42	0.57	3
ogai	kazui	206	1.3157	0.1693	0.4771	7	6.69	0.46	7
ogai	niwatori	587	13.1228	0.7404	0.1021	4	4.21	0.38	7
ogai	shokudo	91	0.2776	0.0832	0.7804	13	9.53	0.73	3
okamoto	karei	194	3.5711	0.6043	0.4678	9	12.45	0.19	5
okamoto	kingyo	632	3.4650	0.9013	0.5850	16	24.03	0.09	5
okamoto	rigyo	119	0.2577	0.0490	0.8499	22	21.25	0.51	3
okamoto	sushi	288	0.7983	0.1455	0.5572	8	8.21	0.41	7
okamoto	tokaido	276	0.1071	0.0433	0.7016	12	14.70	0.26	7
sasa	kikansha	115	20.8736	0.1578	0.0819	4	1.85	0.76	5
sasa	midori	74	1.4028	0.1152	0.4674	5	4.05	0.54	7
shimazaki	bumpai	377	1.7282	0.5855	0.6445	14	23.06	0.06	5
shimazaki	fune	320	3.1831	0.4953	0.6151	17	19.83	0.28	3
shimazaki	mebae	739	1.4973	0.1784	0.3944	6	1.75	0.94	7
shimazaki	namiki	217	0.2989	0.0960	0.5413	6	3.64	0.73	7
shimazaki	shishu	283	1.1646	0.2866	0.4810	7	6.08	0.53	7
shiraki	saite	198	2.2885	0.2657	0.4015	6	3.51	0.74	7
soseki	buncho	409	0.8612	0.0815	0.4941	8	4.32	0.83	5

soseki	hennaoto	82	0.3567	0.2955	0.7203	8	7.60	0.47	5
soseki	kotonone	401	3.2625	0.6202	0.5749	15	17.52	0.29	3
soseki	sakubutsu	183	0.0463	0.0070	0.7325	12	6.37	0.90	5
soseki	tegami	211	2.2489	0.3751	0.5131	9	13.03	0.16	7
suzu	ogon	324	10.4524	0.5815	0.0638	2	0.89	0.64	11
takiji	haha	211	0.7726	0.3625	0.6113	8	16.23	0.04	7
takiji	yukino	565	0.2493	0.0695	0.4080	5	6.25	0.28	7
unno	daino	289	1.1157	0.1607	0.5731	10	11.29	0.34	5
unno	kagaku	108	1.0242	0.1328	0.5156	6	2.15	0.91	7
unno	kibutsu	250	1.7748	0.2114	0.4305	7	13.68	0.06	7
unno	neon	182	1.1837	0.1312	0.4246	5	7.58	0.18	7
unno	tsuki	260	1.7667	0.2264	0.4269	7	15.37	0.03	7
watanabe	akai	194	2.1726	0.5709	0.5182	8	5.25	0.73	5
watanabe	aruhaha	120	0.8454	0.0944	0.5616	7	8.00	0.33	7
watanabe	shohai	298	0.5499	0.1965	0.6890	12	9.22	0.68	5
watanabe	uso	136	0.7294	0.0809	0.5565	7	2.46	0.93	7
yamada	musashino	166	0.3080	0.0362	0.7765	15	9.88	0.83	5
yamashita	ruten	26	1.0755	0.2078	0.5730	5	8.74	0.12	9
yokomitsu	jikan	150	3.6477	0.6335	0.6743	18	19.55	0.36	7
yokomitsu	kikaiy	244	FF						
yumeno	koko	302	2.6289	0.2347	0.4816	10	7.12	0.71	5

Results

Though there are several texts (complete, dialogue, narrative) which do not accord with the Hyperpascal distribution in any case of our different pooling intervals, the overall result satisfactorily indicates that the law of sentence length distributions can also be effectively applied to Japanese. Each individual text which does not conform to the law must be studied separately. If there had been some kind of regulations or restrictive conditions in their creation, and if only these could be detected and allowed for in the analysis, it would be unlikely that such deviations should occur. In the considerable cases of direct speech, testing itself was impracticable simply because there was too little or no dialogue data. The first step in a new direction has been taken, and further development could be expected should sentence lengths be measured by counting the number of clauses. This project will follow shortly.

Writers and Works

Ryunosuke Akutagawa: Giwaku, Jigokuhen, Kage, Kaika no Otto, Aru Katakiuchi no Hanashi, Aruhi no Oishi Kuranosuke, Oritsu to Kora, Rashomon, Uma no Ashi
Sakaguchi Ango: Ishi no Omohi
Takeo Arishima: Chiisaki mono he, Hitofusa no Budo, Kaji to Pochi, Kankan Mushi, Oyako
Osamu Dazai: Ai to Bi nitsuite, Joseito, Kamome, Kashoku, Kirigirisu, Koten Fu, Hashire Merosu, Osan, Oto nitsuite, Sado, Ubasute
Goro Hashimoto: Chizu ni nai Machi
Hatsunosuke Hirabayashi: Yamabuki Cho no Satsujin
Tamio Hojo: Gantai Ki
Tatsuo Hori: Banka, Hana wo moteru Onna, Hoo no saku Koro, Sei Kazoku, Tabi no E

Katsunobu Itakura: Goshiki Onsen Suki Nikki, Haru no Kamikochi he, Yama to Yuki no Nikki
Sachio Ito: Hamagiku, Kooroku, Kyonen, Nanako, Nogiku no Haka
Motojiro Kajii: Deinei, Fuyu no Hae, Kobi, Remon, Setsugo,
Katai Tayama: Ippeisotsu, Shojo Byo, Tokoyo Goyomi
Kan Kikuchi: M Koshaku to Shashinshi, Seni no Tachiba, Shimabara Shinju, Shusse, Wakasugi Saiban Cho
Rohan Koda: Shonen Jidai
Denji Kuroshima: Ana, Dempo, Mogura to Rakuban, Mon, Nusumu Onna, Sato Dorobo, Tongun, Zensho
Shinichi Makino: Kinada Mura, Tsurube to Gekko to
Takitaro Minakami: Yamanote no Ko
Yukio Mishima: Hashi Zukushi
Yuriko Miyamoto: Akarui Kaihin
Kenji Miyazawa: Karasu no Hokutoshichisei
Masayoshi Murai: Soba no Aji to Kuikata Mondai
Sakunosuke Oda: Keiba, Osaka Hakken
Ogai Mori: Asobi, Futari no Tomo, Kazuisuchika, Niwatori, Shokudo
Kanoko Okamoto: Karei, Kingyo Ryoran, Rigyo, Sushi, Tokaido Gojusantsugi
Toshiro Sasaki: Kikansha, Midori no Me
Toson Shimazaki: Bumpai, Fune, Mebae, Namiki, Shishu
Shizu Shiraki: Saite yuku Hana
Soseki Natsume: Buncho, Henna Oto, Koto no Sorane, Sakubutsu no Hihyo, Tegami
Miekichi Suzuki: Ogon Cho
Takiji Kobayashi: Hahatachi, Yuki no Yoru
Juza Unno: Daino Shujutsu, Kagaku ga Heso wo mageta Hanashi, Kibutsudo Jiken, Neon Yokocho Satsujin Jiken, Tsuki no Sekai Tankenki
On Watanabe: Akai Entotsu, Aru Haha no Hanashi, Shohai, Uso
Bimyo Yamada: Musashino
Risaburo Yamashita: Ruten
Riichi Yokomitsu: Jikan, Kikai
Kyusaku Yumeno: Kokonatto no Mi

(All the texts above were downloaded from http://www.aozora.gr.jp/index.html, with the exception of Yukio Mishima's "Hashi Zukushi." This one, still in copyright, was from *Shincho-Bunko no 100 Satsu: CD-ROM Version*, 1995.)

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Confidence intervals and tests for the h-point and related text characteristics

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Abstract. Confidence intervals and tests for recently introduced text characteristics (the *h*-point and its relatives) are derived.

Keywords: text analysis, h-point, a- indicator

1. Introduction

The *h*-point was suggested by Hirsch (2005) as an index of research productivity (mainly) in physics. Popescu (2007) uses it in linguistics as a point which separates highly frequent synsemantic (or auxiliary) words from autosemantic words with lower frequencies. Popescu and Altmann (2006) introduce other three text characteristics – the *k*-point, the *m*-point and the *n*-point, which are modifications or analogies of the *h*-point applied to the frequency spectrum, the cumulative distribution or the reverse order rank-frequency distribution. All four of them can be used to measure vocabulary richness of texts, text coverage, text compactness, analytism and synthetism of language, and so on.

Synsemantic words are usually concentrated in the first classes of the rank-frequency distribution, while much more numerous autosemantic words tend to have significantly lower frequencies. However, there is no sharp boundary separating these two branches; in texts there are a few very frequent autosemantics (they build the theme of the text: see Popescu, Best and Altmann 2007), and/or some synsemantics with low frequencies which may have synonyms used alternately. Therefore we derive confidence intervals for the above mentioned characteristic points. The intervals should cover the area where synsemantics and autosemantics are mixed.

2. Confidence intervals

The *h*-point is an extension of the mathematical fixed point to the actual discrete rank-frequency distribution, $f = f(r)$ (of words in our case), that is by definition is the point $(r, f(r))$ where $f(h) = h$ (if such a point does not exist in the actual distribution, one takes that r whose absolute difference to $f(r)$ is minimum). Table 1 (see below) contains rank-frequency distribution of word forms in Goethe's poem "Erlkönig". The table is presented in Popescu and Altmann (2006).

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Table 1
Erlkönig

Rank r	Frequency f(r)	Cumulative frequency cf(r)	Relative cumulative frequency *F*(*r*)	Rank r	Frequency f(r)	Cumulative frequency cf(r)	Relative cumulative frequency F(r)
1	11	11	0.0489	21	3	104	0.4622
2	9	20	0.0889	22	2	106	0.4711
3	9	29	0.1289	23	2	108	0.4800
4	7	36	0.1600	24	2	110	0.4889
5	6	42	0.1867	25	2	112	0.4978
6	***6***	48	0.2133	26	2	114	0.5067
7	5	53	0.2356	27	2	116	0.5156
8	5	58	0.2578	28	2	118	0.5244
9	4	62	0.2756	29	2	120	0.5333
10	4	66	0.2933	30	2	122	0.5422
11	4	70	0.3111	31	2	124	0.5511
12	4	74	0.3289	32	2	126	0.5600
13	4	78	0.3467	33	2	128	0.5689
14	4	82	0.3644	34	2	130	0.5778
15	4	86	0.3822	35	2	132	0.5867
16	3	89	0.3956	36	2	134	0.5956
17	3	92	0.4089	37	2	136	0.6044
18	3	95	0.4222	38	2	138	0.6133
19	3	98	0.4356	39	2	140	0.6222
20	3	101	0.4489	40-124*	1	225	1

* The ranks 40 to 124 have frequency 1

It is easy to see that the *h*-point is 6, as $f(6) = 6$. We have $N = 225$ and $F(h) = 0.2133$.

Now, let *h* be the *h*-point, cp_h the cumulative probability at *h* and X_h the number of values which are less or equal to *h*. X_h can attain the values $0,1,2,\ldots,N$ with the probabilities which can be derived from (and explained by) an urn scheme consideration. Suppose we randomly place *N* balls into *V* urns labeled $1,2,\ldots,V$. Divide the urns into two groups – the "synsemantic group" consists of the urns $1,2,\ldots,h$, while the urns $h+1, h+2,\ldots,V$ belong to the "autosemantic group". We do not know (and do not need) the probabilities that a ball will be put into a particular urn. All we need is the probability that a ball will be placed into the "synsemantic group" of urns, which is the sum of probabilities of all the urns from that group (or, in other words, it is the cumulative probability at *h*, i.e., cp_h). The probability of putting a ball into the "autosemantic group" of urns is, of course, uniquely determined by the previous one; it is equal to $1 - cp_h$.

$X_h = 0$ (i.e., all balls are in the "autosemantic group" of urns) with the probability

$$P(X_h = 0) = (1 - cp_h)^N,$$

$X_h = 1$ (i.e., one ball is in the "synsematic group", all the other balls are in the "autosemantic group") with the probability

$$P(X_h = 1) = \binom{N}{1} cp_h (1 - cp_h)^{N-1}, \text{ etc;}$$

in general

$$P(X_h = r) = \binom{N}{r} cp_h^r (1 - cp_h)^{N-r}, \; r = 0,1,2,\ldots,N .$$

Hence, X_h has the binomial distribution with the parameters N and cp_h. We note that in general the considered urn scheme is not a non-increasing distribution and the confidence interval is approximate only.

Denote $c\hat{p}_h$ the estimation of cp_h, i.e., $c\hat{p}_h$ is the relative cumulative frequency at h. The binomial distribution can be approximated by the normal distribution. In the next step we obtain the confidence intervals for cp_h:

$$P\left(c\hat{p}_h - u_{1-\frac{\alpha}{2}} \sqrt{\frac{c\hat{p}_h(1 - c\hat{p}_h)}{N}} \le cp_h \le c\hat{p}_h + u_{1-\frac{\alpha}{2}} \sqrt{\frac{c\hat{p}_h(1 - c\hat{p}_h)}{N}} \right) = 1 - \alpha, \qquad (1)$$

where α is the significance level and $u_{1-\alpha/2}$ is the quantile of the standard normal distribution which can be found in any statistical tables or statistical software. The probability remains unchanged if we multiply in (1) all three expressions in the parentheses by N:

$$P\left(Nc\hat{p}_h - u_{1-\frac{\alpha}{2}} \sqrt{Nc\hat{p}_h(1 - c\hat{p}_h)} \le Ncp_h \le Nc\hat{p}_h + u_{1-\frac{\alpha}{2}} \sqrt{Nc\hat{p}_h(1 - c\hat{p}_h)} \right) = 1\text{-}\alpha \qquad (2)$$

We have obtained the confidence interval for cumulative frequencies at the h-point. The interval, where the cumulative frequencies from (2) are attained, is the confidence interval for the h-point. If the cumulative frequencies do not attain exactly the values equal to the confidence interval limits, we suggest taking the highest frequency below the lower interval limit, and the lowest frequency above the upper interval limit.

In the "Erlkönig" we have $c\hat{p} = 0.2133$ and N = 225. For $\alpha = 0.05$ the interval (2) (i.e., the confidence interval for cumulative probabilities) yields (35.95, 60.04). We have $cf(3)$ = 29, $cf(4)$ = 36 and $cf(8)$ = 58, $cf(9)$ = 62. Hence, [3,9] is at least 95% confidence interval for the h-point.

Confidence intervals for the k-point, m-point and n-point (all of them defined in Popescu and Altmann 2006) can be constructed in the same way, using, of course, the respective cumulative probabilities and cumulative frequencies.

3. Tests

3.1. Test for cumulative probabilities corresponding to *h*-points

The approach from the previous section can also be applied to obtain a test for comparing cumulative probabilities corresponding to h-points in two different texts.

Consider two texts. Let h_1, h_2 denote their h-points, cp_{h1}, cp_{h2} the cumulative probabilities

at h_1, h_2 (with $c\hat{p}_{h1}, c\hat{p}_{h2}$ being their estimations) and N_1, N_2 the numbers of word forms or lemmas in the texts, respectively. The statistic

$$U = \frac{\hat{cp}_{h1} - \hat{cp}_{h2}}{\sqrt{\frac{\hat{cp}_{h1}\left(1-\hat{cp}_{h1}\right)}{N_1} + \frac{\hat{cp}_{h2}\left(1-\hat{cp}_{h2}\right)}{N_2}}} \tag{3}$$

has approximately the standard normal distribution. Hence, in terms of corresponding cumulative probabilities, two *h*-points are significantly different if $|U| > u_{1-\alpha/2}$. Recall once more that (3) is a test for comparing cumulative probabilities corresponding to the *h*-points, not for comparing the *h*-points themselves. In other words, (3) can be used to test whether the ratios

$$\frac{\textit{number of word forms (lemmas) with frequencies higher than h}}{\textit{number of all word forms (lemmas)}}$$

in the texts under consideration are significantly different.

As an example, we test the difference of cumulative probabilities corresponding to the *h*-points in two poems – Goethe's "Erlkönig" (see Table 1 above) and Moericke's "Peregrina" (the rank-frequency distribution of word forms is presented in Table 2).

Table 2
Peregrina

Rank r	Frequency f(r)	Cumulative frequency cf(r)	Relative cumulative frequency F(r)	Rank r	Frequency f(r)	Cumulative frequency cf(r)	Relative cumulative frequency F(r)
1	16	16	0.0270	38	2	218	0.3676
2	16	32	0.0540	39	2	220	0.3710
3	12	44	0.0742	40	2	222	0.3744
4	12	56	0.0944	41	2	224	0.3777
5	11	67	0.1130	42	2	226	0.3811
6	10	77	0.1298	43	2	228	0.3845
7	8	85	0.1433	44	2	230	0.3879
8	***8***	93	0.1568	45	2	232	0.3912
9	7	100	0.1686	46	2	234	0.3946
10	7	107	0.1804	47	2	236	0.3980
11	6	113	0.1906	48	2	238	0.4013
12	6	119	0.2007	49	2	240	0.4047
13	6	125	0.2108	50	2	242	0.4081
14	6	131	0.2209	51	2	244	0.4115
15	5	136	0.2293	52	2	246	0.4148
16	5	141	0.2378	53	2	248	0.4182
17	5	146	0.2462	54	2	250	0.4216
18	5	151	0.2546	55	2	252	0.4250
19	5	156	0.2631	56	2	254	0.4283

20	5	161	0.2715	57	2	256	0.4317
21	4	165	0.2782	58	2	258	0.4351
22	4	169	0.2850	59	2	260	0.4384
23	4	173	0.2917	60	2	262	0.4418
24	4	177	0.2985	61	2	264	0.4452
25	4	181	0.3052	62	2	266	0.4486
26	3	184	0.3103	63	2	268	0.4519
27	3	187	0.3153	64	2	270	0.4553
28	3	190	0.3204	65	2	272	0.4287
29	3	193	0.3255	66	2	274	0.4621
30	3	196	0.3305	67	2	276	0.4654
31	3	199	0.3356	68	2	278	0.4688
32	3	202	0.3406	69	2	280	0.4722
33	3	205	0.3457	70	2	282	0.4755
34	3	208	0.3508	71	2	284	0.4789
35	3	211	0.3558	72	2	286	0.4823
36	3	214	0.3609	73	2	288	0.4857
37	2	216	0.3642	74-378*	1	593	1

* The ranks 74 to 378 have frequency 1

We have $h_1 = 6$, $c\hat{p}_{h1} = 0.2133$, $N_1 = 225$ (Erlkönig) and $h_2 = 8$, $c\hat{p}_{h2} = 0.1568$, $N_2 = 593$ (Peregrina). The test (3) yields

$$U = \frac{0.2133 - 0.1568}{\sqrt{\frac{0.2133(1-0.2133)}{225} + \frac{0.1568(1-0.1568)}{593}}} = 1.8153$$

which means that for $\alpha = 0.05$ we do not reject the hypotheses that the cumulative probabilities corresponding to the *h*-points in these poems are equal ($u_{0.975} = 1.96$).

3.2. Test for *a*-indices

The relationship between *h* and *N* can be expressed by a simple equation $N = ah^2$ (suggested by Hirsch 2005, mentioned also in Popescu and Altmann 2006). In fact, the quantity

$$a = \frac{N}{h^2} \tag{4}$$

does not depend any more on *N*, as can be shown using about 200 texts from 20 languages. On the contrary, index *a* is an indicator of language analyticity. The smaller *a* is, the more analytic the language is; the greater *a* is, the more synthetic the language is. As shown in Table 3, this statement can be corroborated empirically using 20 languages.

Table 3
Mean values of *a* in texts of 20 languages
(from Popescu et al. 2007)

Language	Mean a	Language	Mean a
Samoan	4.56	Italian	8.41
Rarotongan	5.02	Romanian	9.15
Hawaiian	5.37	Slovenian	9.19
Maori	5.53	Indonesian	9.58
Lakota	5.69	Russian	10.10
Marquesan	5.69	Czech	10.33
Tagalog	7.24	Marathi	11.82
English	7.65	Kannada	16.58
Bulgarian	7.81	Hungarian	18.02
German	8.39	Latin	19.56

As the index *a* is independent of *N*, it can be used to compare different texts (of different lengths). We need the variances of *a*-indices to construct the test; hence first we look for the distributions of the *h*-points. As a theoretical formula is not known, and all attempts to approximate it failed, a simulation study was used.

It was shown that word rank-frequency distributions in almost all texts can be modeled by the right truncated zeta distribution ($P_x = cx^{-a}$, $x = 1,2,\ldots,V$, with *c* being the normalization constant, cf. Wimmer and Altmann 1999, pp. 577-578), and its parameter can be easily estimated by Altmann-Fitter or other software.

The simulation study can be described as follows ("Erlkönig" being an example again). We generate 225 random numbers (there are 225 words in "Erlkönig") from the right truncated zeta distribution with the parameter 0.6007 (for this parameter value the best fit is obtained) and we find the *h*-point for their rank-frequency distribution. The random numbers generation is repeated 100-times (i.e., we have 100 *h*-points from the samples with the same size and with the same distribution as word frequencies in "Erlkönig"). The *a*-indices for these *h*-points are computed and their variance is found. Finally, the process was repeated 10-times, i.e., 10 variance values (each of them being a variance of 100 *a*-indices) were obtained. We take their mean as the variation of the *a*-index.

The above mentioned numbers of generations may be considered too low, but they require quite a lot of time and our aim is to present the method only.[3]

Now we can test the difference between the *a*-indices in two texts. Denote them a_1, a_2. The statistic

$$U_a = \frac{a_1 - a_2}{\sqrt{Var(a_1) + Var(a_2)}} \tag{5}$$

has, again, approximately the standard normal distribution, i.e., the difference between a_1 and a_2 is significant if $|U_a| > u_{1-\alpha/2}$.

[3] A short simulation program written in *R* can be sent upon request (jmacutek@yahoo.com).

In our texts by Goethe and Moericke we have

$$a_1 = \frac{N_1}{h_1^2} = \frac{225}{6^2} = 6.25 \text{ (Erlkönig)},$$

$$a_2 = \frac{N_2}{h_2^2} = \frac{593}{8^2} = 9.2656 \text{ (Peregrina)}.$$

On the other side, by the above simulation we obtained $Var(a_1) = 48.82$ for "Erlkönig" and $Var(a_2) = 99.05$ for "Peregrina", hence we finally have

$$U_a = \frac{6.25 - 9.2656}{\sqrt{48.82 + 99.05}} = -0.248,$$

which means that for $\alpha = 0.05$ the *a*-indices for "Erlkönig" and "Peregrina" are not significantly different.

4. Examples

In order to check the intralinguistic and extralinguistic differentiation of texts we performed the test for differences of cumulative probabilities corresponding to the *h*-points on 13 texts (by Goethe in German and Eminescu in Romanian, Table 4). The list of texts is given in the Appendix. The matrix is antisymmetric, i.e., the number in the *i*-th row and *j*-th column and the number in the *j*-th row and *i*-th column have the same absolute values but opposite signs. The critical value is ±1.96.

Table 4
U-test for the difference between cumulative probabilities
corresponding to *h*-points

	G 05	G 09	G 10	G 11	G 12	G 14	G 17	R 01	R 02	R 03	R 04	R 05	R 06
G 05	0	0.60	1.84	**2.64**	0.91	1.09	0.43	0.02	-0.38	0.33	0.86	0.20	0.28
G 09	-0.60	0	1.33	**2.16**	0.46	0.69	-0.01	-0.73	**-2.12**	0.37	**2.17**	-0.06	0.19
G 10	-1.84	-1.33	0	0.77	-0.58	-0.26	-0.99	**-2.24**	**-3.57**	-1.17	0.49	-1.51	-1.17
G 11	**-2.64**	**-2.16**	-0.77	0	-1.21	-0.83	-1.58	**-3.25**	**-4.63**	**-2.11**	-0.44	**-2.43**	**-2.01**
G 12	-0.91	-0.46	0.58	1.21	0	0.23	-0.38	-1.01	**-1.97**	-0.24	1.02	-0.53	-0.32
G 14	-1.09	-0.69	0.26	0.83	-0.23	0	-0.58	-1.19	**-2.03**	-0.50	0.61	-0.76	-0.56
G 17	-0.43	0.01	0.99	1.58	0.38	0.58	0	-0.46	-1.34	0.26	1.44	-0.03	0.15
R 01	-0.02	0.73	**2.24**	**3.25**	1.01	1.19	0.46	0	-1.86	1.38	**3.81**	0.78	0.98
R 02	0.38	**2.12**	**3.57**	**4.63**	**1.97**	**2.03**	1.34	1.86	0	**3.17**	**5.80**	**2.41**	**2.42**
R 03	-0.33	-0.37	1.17	**2.11**	0.24	0.50	-0.26	-1.38	**-3.17**	0	**2.22**	-0.49	-0.15
R 04	-0.86	**-2.17**	-0.49	0.44	-1.02	-0.61	-1.44	**-3.81**	**-5.80**	**-2.22**	0	**-2.59**	**-2.00**
R 05	-0.20	0.06	1.51	**2.43**	0.53	0.76	0.03	-0.78	**-2.41**	0.49	**2.59**	0	0.27
R 06	-0.28	-0.19	1.17	**2.01**	0.32	0.56	-0.15	-0.98	**-2.42**	0.15	**2.00**	-0.27	0

As can be seen, not only different authors but also different works of the same author may display significant differences, even in the same genre. Hence the *h*-point and the derived indicator *a* can be considered text-dependent characteristics.

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Appendix : Texts used

G 05:	Goethe, J.W.v.	Der Gott und die Bajadere
G 09:	Goethe, J.W.v	Elegie 19
G 10:	Goethe, J.W.v	Elegie 13
G 11:	Goethe, J.W.v	Elegie 15
G 12:	Goethe, J.W.v	Elegie 2
G 14:	Goethe, J.W.v	Elegie 5
G 15:	Moericke, E.	Peregrina
G 17:	Goethe, J.W.v	Der Erlkönig
R 01:	Eminescu, M.	Luceafarul - Lucifer
R 02:	Eminescu, M.	Scrisoarea III - Satire III
R 03:	Eminescu, M.	Scrisoarea IV - Satire IV
R 04:	Eminescu, M.	Scrisoarea I - Satire I
R 05:	Eminescu, M.	Scrisoarea V - Satire V
R 06:	Eminescu, M.	Scrisoarea II - Satire II

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Investigation of the Zipf-plot of the extinct Meroitic language

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Abstract: The ancient and extinct language Meroitic is investigated using Zipf's Law. In particular, since Meroitic is still undeciphered, the Zipf law analysis allows us to assess the quality of current texts and possible avenues for future investigation using statistical techniques.

Keywords: Meroitic, Zipf's law

1. Introduction

Zipf's law is one of the oldest and most fundamental numerical measures of text structure (Zipf, 1948). There have been many studies of Zipf's Law affirming its universal importance and prevalence among human languages. Rank-frequency distributions of word forms in human languages in most cases abide by the right-truncated Zipf distribution (Zipf 1948; McCowan, et. al. 1999, 2005), however, possessing such a plot is a necessary, but not sufficient, measure of whether the repertoire can represent a real human language. Zipf's work was later expanded and given a firm mathematical footing by connecting it to the burgeoning area of information theory. Both Mandelbrot (1953) and Naranan & Balasubrahmanyan (1992a, b) derived results similar to Zipf's Law by using an entropy based fitness with Mandelbrot using the letter as the primary symbol and Naranan & Balasubrahmanyan using the word as the primary symbol. Structured discourse is not the only possible origin of power law behavior though. Miller (1957) & Li (1992) among others show that a text of random words and spaces can also demonstrate power law behavior. This so-called "monkey language", named for the amusing concept of monkeys randomly typing on typewriters, can produce a Zipfian spectrum with respect to the probability vs. rank of word occurrence. However, Ferrer i Cancho & Solé (2002) have shown that "monkey language" does not present a completely realistic reproduction of human language statistics. In "monkey language", the inverse Zipf plot where the probability of a word having a frequency of appearance in the text P(*f*) is plotted vs. frequency shows non-power law behavior in contrast to the power law behavior of human languages. Thus it seems "monkey language" does not render Zipf's Law a trivial aspect of linguistic statistics. Therefore Zipf's law is still an important and perhaps a fundamental aspect of human languages whose significance is still heavily debated and researched.

The Zipf plots for many modern languages have been well studied. In this paper, the Zipf plot of the word occurrence frequencies for a corpus of Meroitic texts is investigated in the same light. Since Meroitic has still been undeciphered for almost 100 years, this author believes new techniques borrowed from quantitative linguistics may be useful in illuminating the structure and meaning of the language. As a litmus test for further study, a basic adherence to Zipf's Law can

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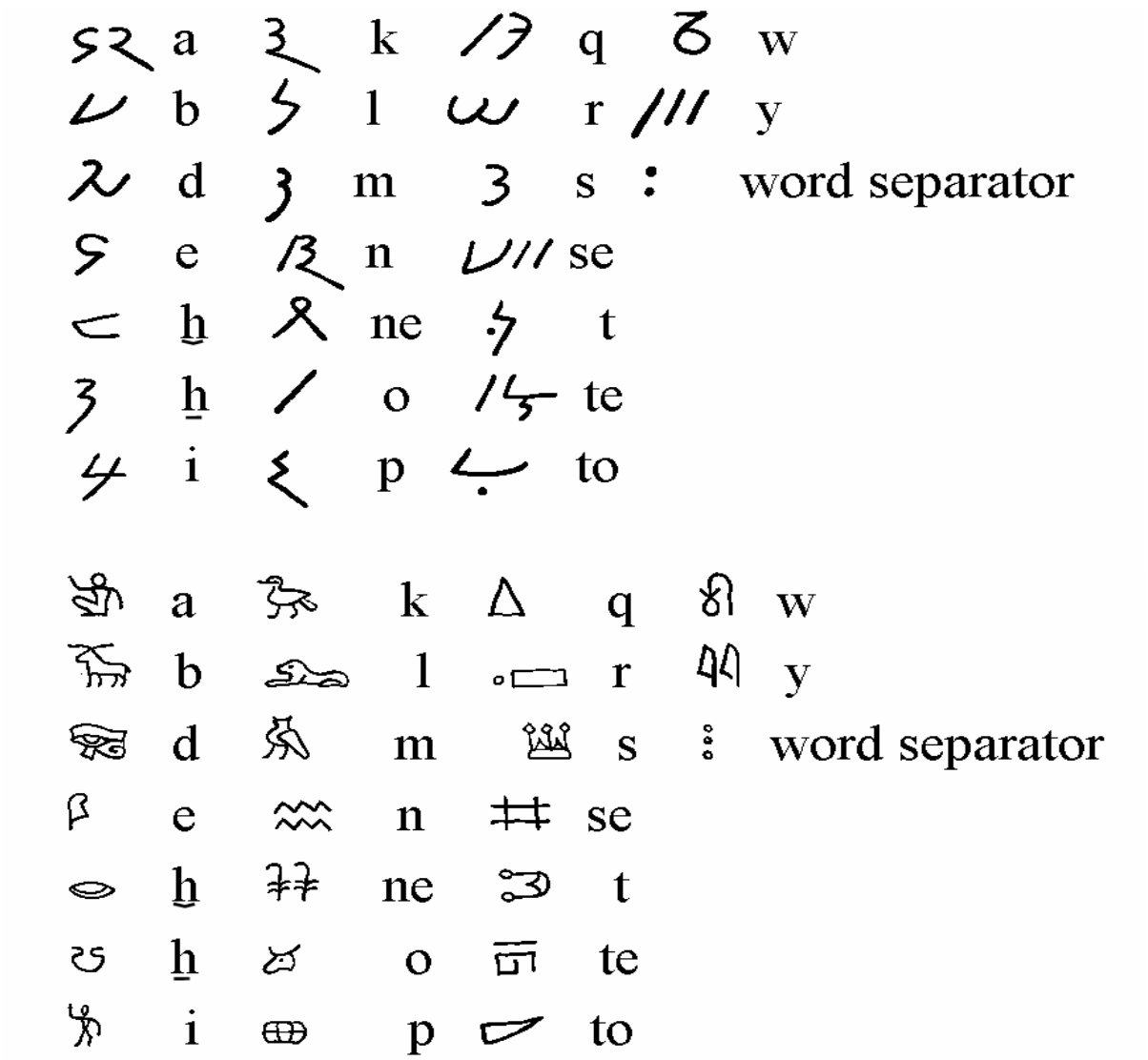
confirm the texts currently in possession have lexical statistics in a manner consistent with other languages and thus may be amenable to other types of mathematical analysis.

2. A Short History of Meroitic (Török 1997; Lobban 2004)

Meroitic was the written language of the ancient civilization of Kush, located for centuries in what is now the Northern Sudan. The word 'Meroitic' derives from the name of the city Meroë, which was located on the East bank of the Nile south of where the Atbara River flows off to the east. It is the second oldest written language in Africa after Egyptian hieroglyphs. It is a phonetic language with both a hieroglyph form using some adopted Egyptian hieroglyphs and a cursive form similar to Egyptian Demotic writing. The language had one innovation uncommon in ancient written languages such as Egyptian hieroglyphics or Greek in that there was a word separator, similar in function to spaces in modern scripts, that looks similar to a colon (see Table 1).

Table 1
Meroitic Cursive and Hieroglyphic words and their transliterations



Meroitic was employed starting the 2nd century BC and was continuously used until the fall of Meroë in the mid 4th century AD. The script was rediscovered in the 19th and 20th centuries as Western archaeologists began investigating the ancient ruins in the Sudan. The first substantial progress in deciphering Meroitic came around 1909 when British archaeologist Francis Llewellyn Griffith was able to use a bark stand which had the names of Meroitic rulers in Meroitic and Egyptian hieroglyphs. The Meroitic hieroglyphs were then corresponded to the Meroitic cursive script and it was then possible to transliterate Meroitic (see Table 1[2]). Some vocabulary was later deciphered by scholars including loan words from Egyptian, gods, names, honorifics, and common items (see Table 2). However, the language remains largely undeciphered. The greatest hope for decipherment, a Rosetta stone type of tablet containing writing in Meroitic and a known language such as Egyptian, Greek, Latin, or Axumite, has yet to be found. Further confounding research is the confusion regarding which language family Meroitic belongs to. Cognate analysis has proceeded extremely slowly since it is disputed to which language family Meroitic properly belongs. Recent work by (Rilly, 2004) has suggested that Meroitic belongs to the North Eastern Sudanic family, however, full decipherment has still proceeded very slowly.

Table 2
Top 20 ranked words and rank-frequency count distributions for REM 1003

Regular			**Bound Morpheme Removed**		
Word	**Count**	**Possible Meaning**	**Word**	**Count**	**Possible Meaning**
seb	10	?	li	25	particle
qoleb	8	these??	seb	10	?
qor	7	king	qoleb	8	these??
tkk	7	?	qor	7	king
amnp	5	Amun of Napata	tkk	7	?
abrsel	4	Men	qes	6	Kush
kdisel	4	Women	amnp	5	Amun of Napata
abr	3	Man	abrsel	4	Men
adgite	3	?	kdisel	4	Women
arseli	3	?	lo	4	particle('is a/the')
grpgel	3	to command/commander?	te	4	locative particle
grpglke	3	to command/commander?	abr	3	Man
kdi	3	women	adgite	3	?
mno	3	Amun	arse	3	?
ns	3	?	grpgel	3	to command/commander?
qes	3	Kush	grpglke	3	to command/commander?
qesli	3	Kushite? (adj/noun)?	kdi	3	Woman
qesto	3	Kushite? (adj/noun)?	mno	3	Amun of Napata
wwikewi	3		ns	3	
100 (number)	2		pqr	3	Prince

[2] [Taken from the latest font set for Meroitic Hieroglyphic and Cursive characters developed by the Meroitic scholars Claude Carrier, Claude Rilly, Aminata Sackho-Autissier, and Olivier Cabon. Web Address: http://www.egypt.edu/etaussi/informatique/meroitique/meroitique01.htm]

In light of the slow progress by traditional linguistics methods to translate the language, this author has begun to investigate various methods such as natural language processing and types of statistical analysis to try to gleam more information about the language, its structure, and meaning. This is not an entirely new approach since Meroitic was one of the earliest ancient languages to be investigated using computers (Leclant 1978; Heyler 1970, 1974).

3. The Zipf Plot of Meroitic

3.1 Mathematical Techniques

The author analyzed the texts by using a computer program to fit them to the Zipf version of the zeta function where the frequency of a word given its rank is given by the following equation:

$$(1) \qquad f_z = \frac{C}{z^{\alpha}}, \quad z = 1,2,3...n$$

Where f_z is the probability of the word of rank z for ranks 1 to n (right-truncated), C is the normalizing constant, and α is the scaling factor of the power law behavior; f_z is considered zero for all z greater than n.

The author analyzed 25 of the longest and most complete texts. These typically have at least 20 different word tokens with a highest frequency count of at least 2. These texts were from the Répertoire d'épigraphie méroïtique (REM), the largest collection of writings in the Meroitic script. Except for a few large stelae, such as those by the Meroitic king Taneyidamani (REM 1044), almost all Meroitic scripts available are funerary texts which follow a similar and well-recognized formulaic pattern for the obituaries recorded within them. The Altmann-Fitter statistical software was used to calculate the parameters and the Zipf distribution and fit it to the data.

Some spellings were standardized since many words were obviously spelled in different ways since there was no standard spelling in Ancient Kush. The author was judicious, however, and did not make specious replacements of similar looking words but words that were used in identical contexts and almost identical spellings. Words which were partially illegible were not corrected and counted as a single instance of an “illegible” word.

In the end, two Zipf distributions were created. The first, is a standard Zipf distribution of the frequency and rank of individual words in the corpus. Individual words were distinguished by being separated by the separator character (which can be found in Table 1). The second Zipf distribution took into account the presence of many conspicuous bound morphemes in the Meroitic language. Many Meroitic verbs, as well, as some nouns have suffixes which contain grammatical meaning. For example, it is known that the suffix *telowi* or *teli* is appended to the name of a place, such as a city, to indicate that the subject of the sentence was affiliated with this place. There is also an extremely common suffix *lowi* or *li* that is appended to nouns that may denote the noun as an indirect object in the sentence. Their definitions are still tenuous, however, these bound morphemes are very common and were separated into independent words for the second Zipf plot. The six bound morphemes separated out were “qo”, “lo”, “li”, “te”, “lebkwi”, “mhe”. They were separated in the manner:

qo → separated out to "qo"
lo → separated out to "lo"
li → separated out to "li"
lowi → lo and wi
lw → separated out to "lw"
telowi → te and lo and wi
teli → te and li
lebkwi → lebk and wi
atomhe → ato and mhe
atmhe → at and mhe
qowi → qo and wi

3.2. Results

The numerical results for each of the individual texts, as well as the entire corpus, is presented here in Table 3. *N* is the total number of words and *V* is the number of distinct word types. BM indicates a bound morpheme separated out text.

Table 3
Rank-frequency distribution results for texts

			Zeta Distribution (Zipf)					Right-Truncated Zeta Distribution				
Text	N	V	a	C	χ^2	P(χ^2)	DF	a	C	X^2	P(χ^2)	DF
REM 0088	37	33	0.78	0.79	29.26	0.01	13	0.32	0.03	1.01	1.0	21
REM 0088-BM	53	37	0.92	0.51	27.25	0.07	18	0.64	0.09	4.70	1.0	24
REM 0129	82	72	0.61	0.62	50.98	0.04	35	0.36	0.06	4.79	1.0	49
REM 0129-BM	116	75	0.78	0.46	52.84	0.14	43	0.73	0.15	17.37	1.0	51
REM 0217	40	37	0.88	0.72	28.86	0.01	14	0.32	0.06	2.44	1.0	23
REM 0217-BM	70	42	0.99	0.45	31.55	0.09	22	0.81	0.16	10.96	1.0	27
REM 0221	32	25	0.91	0.52	16.78	0.08	10	0.63	0.13	4.07	1.0	14
REM 0221-BM	48	29	1.09	0.48	23.23	0.06	14	0.76	0.14	6.57	1.0	19
REM 0223	23	21	0.09	3.29	75.83	0	2	0.29	0.02	0.56	1.0	13
REM 0223-BM	38	26	0.96	0.54	20.68	0.06	12	0.66	0.05	1.74	1.0	16
REM 0229	30	29	1.08	0.91	27.21	0	10	0.40	0.08	2.50	1.0	16
REM 0229-BM	49	33	0.87	0.51	24.80	0.07	16	0.70	0.09	4.21	1.0	21
REM 0237	29	26	0.10	2.87	83.23	0	4	0.36	0.06	1.68	1.0	16
REM 0237-BM	55	32	1.05	0.33	18.10	0.32	16	0.76	0.05	2.51	1.0	21
REM 0247	45	38	0.82	0.65	29.11	0.02	16	0.43	0.07	3.37	1.0	25
REM 0247-BM	59	39	0.98	0.41	24.48	0.18	19	0.73	0.11	6.34	1.0	25
REM 0259	28	27	0.12	2.33	65.35	0	4	0.2	0.02	0.59	1.0	17
REM 0259-BM	42	31	0.86	0.51	21.44	0.09	14	0.57	0.06	2.59	1.0	20
REM 0264	33	31	0.15	2.16	71.15	0	6	0.23	0.02	0.73	1.0	20
REM 0264-BM	50	33	0.86	0.5	24.94	0.07	16	0.62	0.04	1.98	1.0	22
REM 0278	30	30	0.21	1.82	54.60	0	6	0	0	0	0	N/A
REM 0278-BM	50	35	0.08	4.97	248.6	0	10	0.7	0.16	7.88	1.0	22
REM 0289	48	39	1.00	0.59	28.08	0.03	16	0.48	0.06	2.91	1.0	25
REM 0289-BM	65	43	0.87	0.47	30.66	0.10	22	0.65	0.07	4.53	1.0	29
REM 0297	24	23	0.92	0.72	17.40	0.03	8	N/A	N/A	N/A	0	N/A
REM 0297-BM	43	27	0.94	0.45	19.25	0.12	13	0.74	0.06	2.43	1.0	17
REM 0324	27	26	0.87	0.68	18.28	0.03	9	0.21	0.02	0.58	1.0	16
REM 0324-BM	45	31	0.91	0.48	21.70	0.12	15	0.66	0.05	2.42	1.0	20
REM 0386	27	25	0.65	0.97	26.27	0	8	0.31	0.04	1.05	1.0	15
REM 0386-BM	43	28	1.08	0.46	19.64	0.10	13	0.72	0.09	4.04	1.0	18
REM 0387	31	28	0.14	2.45	75.85	0	5	0.27	0.02	0.76	1.0	18
REM 0387-BM	48	31	1.00	0.44	21.18	0.13	15	0.66	0.05	1.59	1.0	21
REM 0521	54	50	0.14	1.51	81.57	0	15	0.22	0.02	1.19	1.0	35
REM 0521-BM	80	54	0.94	0.43	34.60	0.15	27	0.69	0.11	9.04	1.0	36

REM 1003	327	230	0.54	0.23	74.41	1.0	155	0.46	0.03	9.11	1.0	181
REM 1003-BM	360	227	0.64	0.21	74.09	1.0	157	0.58	0.04	15.05	1.0	174
REM 1020	36	31	0.99	0.66	23.65	0.02	12	0.37	0.05	1.79	1.0	20
REM 1020-BM	56	36	0.99	0.45	25.2	0.12	18	0.73	0.10	5.49	1.0	23
REM 1044 (A-D)	435	362	0.45	0.21	93.35	1.0	235	0.40	0.06	26.23	1.0	261
REM 1044(A-D)-BM	449	364	0.48	0.21	95.70	1.0	239	0.43	0.07	30.09	1.0	263
REM 1057	41	38	0.97	0.99	40.41	0	15	0.80	0.45	18.61	0.48	19
REM 1057-BM	61	41	0.92	0.49	29.98	0.09	21	0.69	0.11	6.76	1.0	27
REM 1064	55	48	0.69	0.7	38.37	0.01	21	0.28	0.02	1.36	1.0	34
REM 1064-BM	83	50	0.87	0.39	32.26	0.26	28	0.7	0.05	4.33	1.0	36

Table 4 shows the rank frequency distribution for two of the texts used, REM 1003 (the Amanirenas/Akinidad stela) and REM 1020, this information is provided to allow readers to confirm the results with their own analysis. Interestingly, REM 1003 had less word types with the bound morphemes removed since many word types in the regular version appear both alone or with one or more types of suffixes, so separated out you are left with less word types.

Table 4
Rank-Frequency Counts: REM 1020 and REM 1003

REM 1020

Normal		**Bound Morpheme Removed**	
Rank	**Frequency**	**Rank**	**Frequency**
1	4	1	9
2	2	2	8
3	2	3	4
4-31	1	4	2
		5	2
		6	2
		7-36	1

REM 1003

Normal		**Bound Morpheme Removed**	
Rank	**Frequency**	**Rank**	**Frequency**
1	10	1	25
2	8	2	10
3	7	3	8
4	7	4	8
5	5	5	7
6	4	6	7
7	4	7	6
8-19	3	8	5
20-54	2	9	4
55-230	1	10	4
		11	4
		12	4
		13	4
		14-24	3
		25-61	2
		62-226	1

Below are the plots of the data listed. Figure 1 and Figure 2 show the data plots of one of the larges texts, REM 1003 in both normal and bound morpheme removed versions.

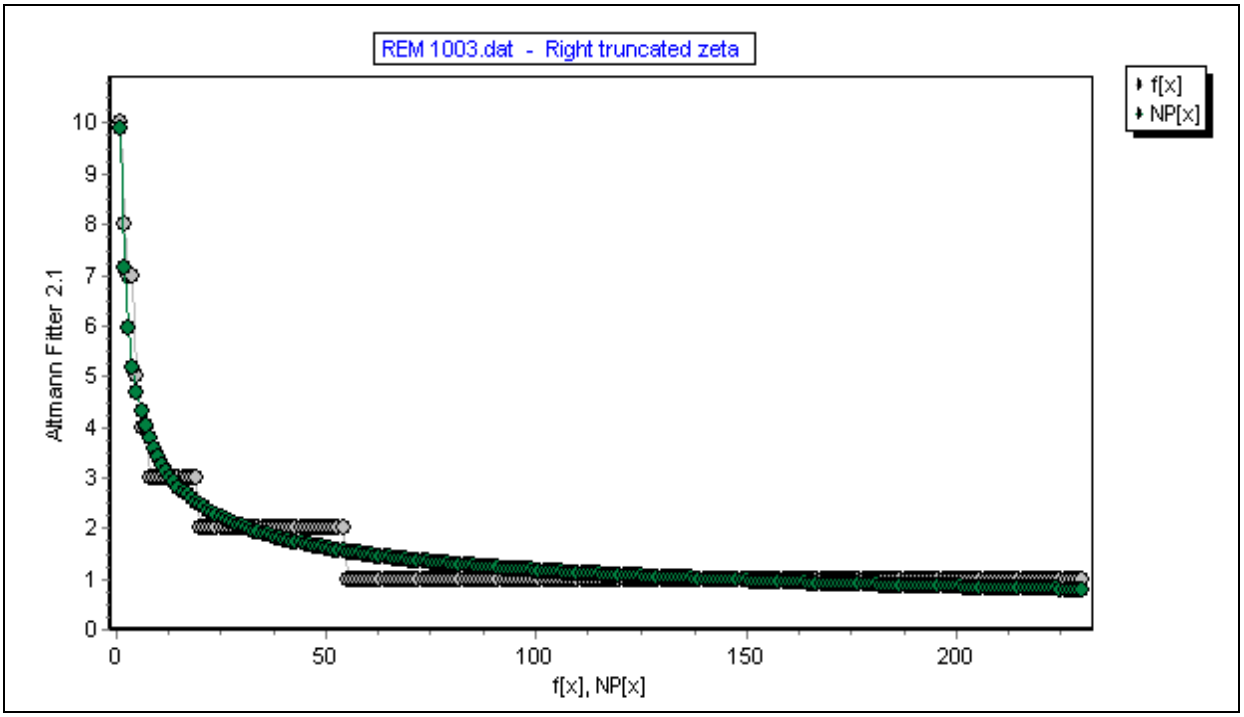


Figure 1. REM 1003 Original Text

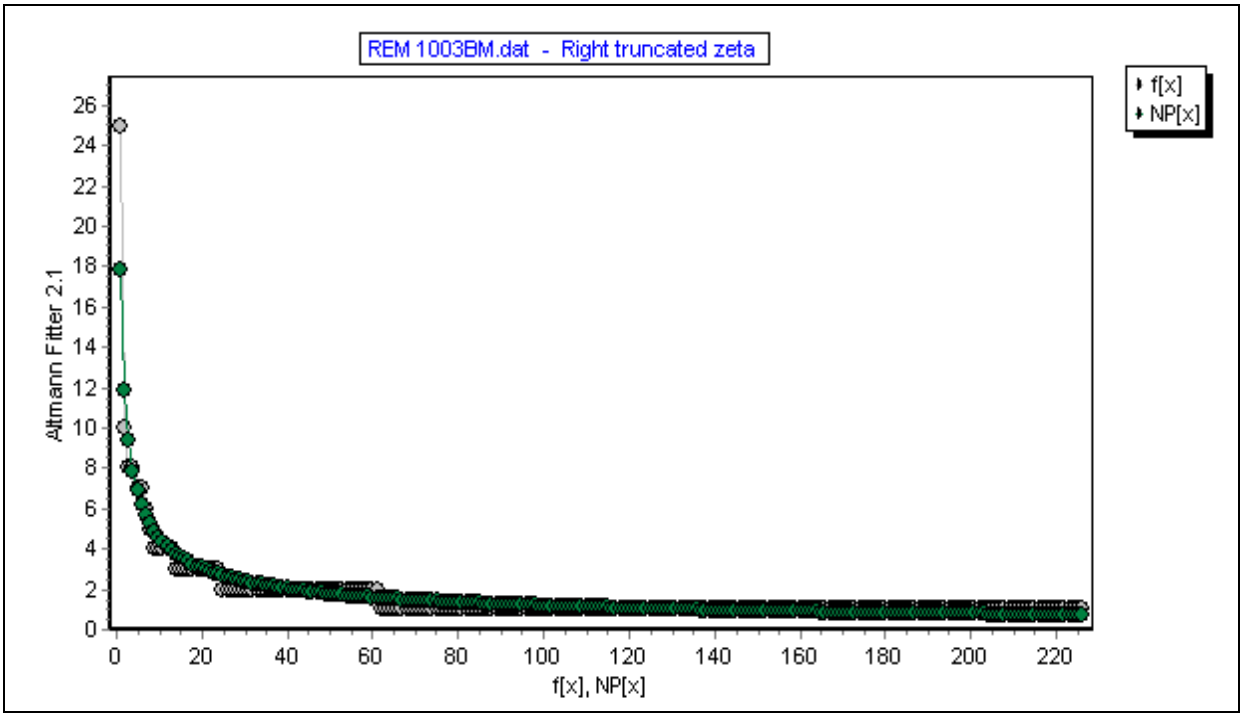


Figure 2. REM 1003 Bound Morpheme Separated

Most texts were funeral texts with a very redundant and standardized structure. The words, *wosi* (Isis), *soreyi* (Osiris), *terike* (begotten of), and *tedge* (born of) are present in almost all of the funeral texts and this fact is accounted for in their high ranks. Outside of the funeral texts and their repetitious obituaries, only several long stelae remain which seem to be documentaries of the role of the ruler it is dedicated to (ie. Akinidad, Haramadoye, Taneyidamani, etc.). Given this intuitive result, perhaps the language is more accurately represented with the bound morphemes separated since this populates the necessary high frequency words lacking in the first analysis.

Overall, the Meroitic language shows that it behaves like all other human languages in following the Zipf law for word frequency. This starting point allows us to more confidently use further statistical techniques to further understand Meroitic.

4. Conclusion

The above analysis indicates that Meroitic, despite being undeciphered, statistically behaves like all other human languages with a word frequency distribution exhibiting power law behavior. Though our texts are very short, the original requirement of $a \approx 1$ cannot be maintained. If we use the more realistic version of Zipf´s law, namely the truncation at the right side of the distribution, the value of the parameter a is not characteristic of human language but more probably of the given text or genre.

Modern linguistic theory dictates it is unlikely that one can completely reconstruct a natural language based only on statistical data. However, with words that are already known, perhaps one can use context and other methods to infer currently hidden meanings in the Meroitic texts. This paper serves as a foundation for such work by demonstrating that Meroitic behaves statistically like other languages in adhering to Zipf word frequency distributions. Possible future statistical analysis could use some similarity measure to relate unknown words to current known ones and allow us to perhaps infer the meanings of some unknown words by seeing which known words they are similar to. If such an analysis would even be moderately successful, it would open new doors of analysis both in archaeology and mathematical linguistics.

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A psycholinguistic application of synergetic linguistics

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Abstract: The paper presents a new attempt to analyse the relationship between word familiarity and word frequency within the framework of synergetic linguistics. Whereas in psychology it is customary to apply correlational analyses to such questions the current paper sets up a functional model and tests it on empirical data from two large corpora and a psycholinguistic database.

Keywords: psycholinguistics, word familiarity, word frequency, synergeticlinguistics

Introduction

The modeling paradigm of synergetic linguistics (see Köhler 1986, 1990, 2005) is well suited to interdisciplinary work and to the creation of models which allow the interconnection of several disciplines. By looking at two quantities, word frequency and word familiarity, the example considered here shows how an interface between the two neighboring disciplines of psychology and linguistics can be created in this way.

Rapp (2005) considered the relationship between the occurrence frequencies of words in a corpus and the subjective judgments of their familiarity provided by human subjects. The aim of this study was to provide evidence that word occurrences are observed by human perception, and that the frequencies of words are stored in memory. It is argued that this could be demonstrated if it were the case that, when subjects are asked questions related to word frequencies, the answers tend to be correct.

However, in such experiments it turns out that it is almost impossible for subjects to give correct estimates of absolute values of word frequencies. Much better results are achieved, however, if judgments of word familiarity are elicited. This can be measured using, for example, a grade scale of 1 to 7. Psychologists have conducted such experiments on a large scale, and their results were compared with word frequencies as found in balanced corpora. The simplifying assumption was made that the word frequencies as obtained from the corpora are representative of the language environment of the test subjects.

In the study it was shown that there is a strong correlation of $r = 0.75$ between the corpus frequencies of words and the familiarity ratings for those words provided by test subjects. Similar investigations by other authors led to similar results. Underwood et al. (1965) report a correlation of $r = 0.85$, and Kreuz (1987) a correlation of $r = 0.75$. By comparison, the correlations of familiarity ratings between different groups of test subjects were only slightly higher than this (between 0.77 and 0.88). This provides some evidence in favor of the hypothesis given above, namely that word frequencies are stored in human memory. However, it should not be forgotten that a high correlation is not sufficient to imply causality.

Also, correlation analysis, although a standard method in psychology, is a weak and sometimes misleading method for describing relationships of the kind considered here, which are nonlinear. This is because correlations can only take the linear parts of a relationship into ac-

count, and even those only as the strength of a tendency. To avoid these drawbacks it makes sense to conduct a functional analysis, for example a nonlinear regression.

Therefore, this study attempts to theoretically derive the relationship between the corpus frequencies of words and their familiarity judgments as provided by test subject, as a functional dependency in the framework of synergetic linguistics. The resulting model is empirically tested using the same data as was used by Rapp (2005).

Data

Our source of familiarity judgments from test subjects was the online version of the *MRC*[1] *Psycholinguistic Database* (Coltheart, 1981a; 1981b), for which Craig Clark has developed a user friendly and flexible web interface.[2] According to Wilson (1988) the MRC database provides familiarity estimates for 9392 entries. Table 1 shows a few examples. However, these 9392 entries correspond to only 4920 words, as in the MRC database an entry is defined as the combination of a word with its part of speech. Therefore, ambiguous words that can occur as different parts of speech are counted more than once.

The familiarity estimates are based on judgments from test subjects who were asked to assign to each word a familiarity value on the usual scale between 1 (for a word unknown to a subject) and 7 (for a very familiar word from everyday language). Collections of such familiarity judgments are usually referred to as *familiarity norms*. In order to provide estimates for as many words as possible, familiarity judgments from three different experiments were included in the MRC database. The experiment conducted by Toglia & Battig (1978) contributed 2854 words, the experiment by Gilhooly and Logie (1980) contributed 1944 words, and Paivio et al. (1968) provided an unpublished expanded version of their data consisting of 2310 words. As there is some overlap in vocabulary, Table 2 lists how many words the three studies have in common. It also shows the high correlations of the familiarity ratings between the three groups of test subjects.

When creating the MRC psycholinguistic database, on the basis of these high correlations Coltheart (1981a) decided to merge the three studies by averaging the values corresponding to the same words. Beforehand he had adjusted the overall means and standard deviations of the three studies. In order to not pretend unjustifiable high accuracies of the merged familiarity judgments, Coltheart decided to round the floating point numbers that were the result of the averaging process after two decimals. He then multiplied the resulting values by 100 so that the range of familiarity judgments in the MRC database is not between 1 and 7, but between 100 and 700, as stated by Wilson (1988). However, to be more precise, it must be noted that the process of adjusting the means and standard deviations of the three underlying studies led to some distortion of this range, so that actually a few values below 100 can be observed.

[1] MRC stands for the *Medical Research Council*, the funding organisation for the project.
[2] http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm

Table 1
The 10 words with the highest and the lowest familiarities in the MRC Psycholinguistic Database together with their frequency in the Brown Corpus
(words with a corpus frequency of zero are not included).

WORD	FAM.	FREQ.
BREAKFAST	657	53
AFTERNOON	655	106
CLOTHES	652	89
BEDROOM	646	52
DAD	646	15
GIRL	645	220
RADIO	644	120
BOOK	643	193
NEWSPAPER	641	65
WATER	641	442

WORD	FAM.	FREQ.
LOQUACITY	144	1
MIEN	143	1
YUCCA	136	1
BURGHER	133	1
PAEAN	133	2
OBELISK	131	6
PLENIPOTENTIARY	128	1
TAPIS	118	1
METIS	101	1
VERDANT	98	1

Table 2
Vocabulary overlap and correlations between three familiarity norms according to Coltheart (1981a).

FAMILIARITY NORMS	COMMON WORDS	CORRELATION
Toglia & Battig / Gilhoooly & Logie	597	0.77
Paivio et al. / Gilhooly & Logie	427	0.88
Toglia & Battig / Paivio et al.	882	0.88

Estimates of the word frequencies in everyday language as experienced by the test subjects were derived from two balanced corpora of English which, given the impossibility of a perfect solution, seemed best suited to model the language environment of an average subject. These were the *Brown Corpus* (Francis & Kučera 1989), which comprises about 1 million words, and the *British National Corpus* (BNC; Burnard & Aston 1998) consisting of about 100 million words. The database uses uppercase letters only (see Table 1), a reflection of the time of its creation. Therefore, before counting the corpus frequencies of words we preprocessed the two corpora to capitalise them throughout. Although occasionally this may add some ambiguity, we do not expect a major impact on the word counts of the particular vocabulary we are interested in.

The Model

If, in analogy to other relationships between properties of words, it is assumed that the familiarity of a word shows a relative increase as the frequency of perception of that word grows, then this can be expressed as a differential equation:

$$\frac{y'}{y} = \frac{B}{x}, \tag{1}$$

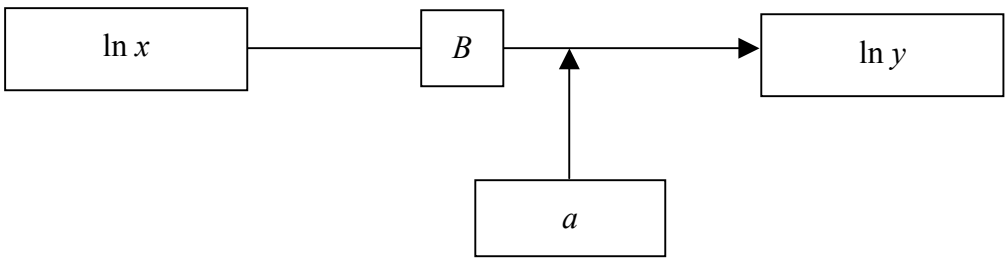
where y is the degree of familiarity, y' its first derivative, B is a proportional operator, and x the word frequency. The solution of this differential equation is obtained by integrating both sides of the equation:

$$y = Ax^B . \tag{2}$$

This result conforms with the schema of hypotheses concerning other lexical properties which have previously been studied within the framework of synergetic linguistics (Köhler 1986). In this framework, by computing the logarithm of the above result, Equation (2) is linearised, which allows the theory of linear operators and graph theory to be applied. Thus, it becomes possible to depict the relationships clearly and illustratively in the form of a diagram permitting a mathematically correct interpretation. This transformation leads to the following equation:

$$\ln y = \ln a + B \ln x \tag{3}$$

With $a = \ln A$, the equation (3) can be diagrammatised as follows:

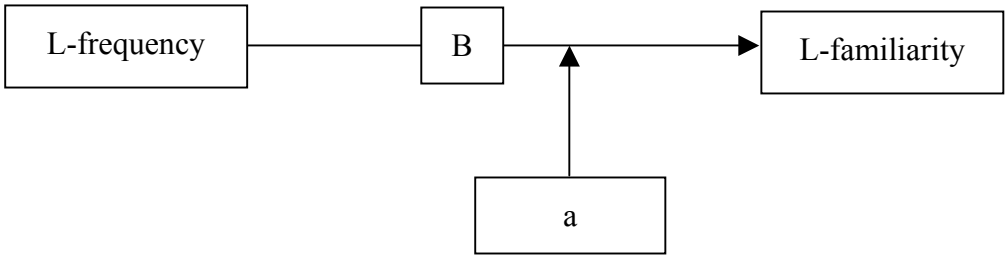


The rules governing the interpretation of such a diagram dictate that nodes directly connected by an edge are to be *multiplied*, whereas nodes only indirectly connected via orthogonal edges are to be *added*.

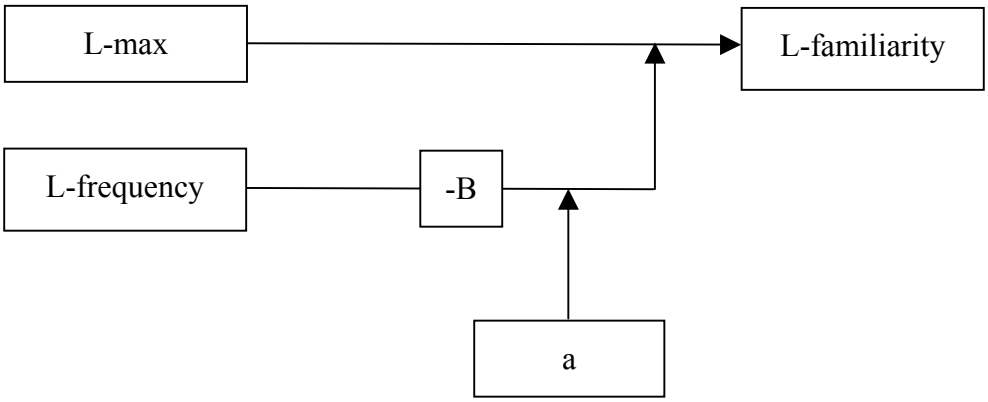
In our example, node B is a proportional operator modifying the degree of the increase in familiarity with growing frequency. Node a should also be interpreted as a factor influencing familiarity. This factor could reflect the observation, found in the psychological literature, that word familiarity depends not only on frequency of perception, but also on the relevance and familiarity of a word's meanings (cf. Le Ny / Cordier 2004). Another plausible mechanism was described by Wettler, Rapp, and Sedlmeier (2005): if a person perceives a stimulus word, other words are evoked in their memory, which are called *associations*. Thus, the generation process takes place unconsciously and automatically. When test subjects are asked for familiarity judgments of words, the situation is similar to the association experiment in that subjects are also exposed to lists of words. Consequently, perception of the words will likewise evoke the generation of associations. We could now assume that the familiarity ratings given by subjects are not based solely on the perception frequency of the respective stimulus word, but on a function (e.g. mean) of the perception frequencies of all activated words, i.e. of the stimulus word *and* its associations. From this we could, for example, explain the observation that, despite differences in their actual occurrence frequency, different inflected forms of the same root word usually receive similar ratings – at least if we assume that all inflectional variants are highly associated. An example would be "[it] rains" versus "[you] rain", where due to semantic constraints the form of the third person has the highest frequency.

This partial hypothesis could be tested empirically in several ways. One possibility would be to use lemma frequencies instead of word counts, or to use weighted means of the inflectional forms relating to the same root form (which, however, also requires lemmatization of the corpus). Another possibility would be the comparison of similar experiments based on a number of different languages, some highly inflectional, others less so. However, this has not been done yet and will be left for future investigation. On the other hand it should be noted that the synergetic modelling and a test of our initial hypothesis do not depend on the interpretation of the factor *a*.

If in our diagram we replace *x* with the frequency and *y* with the familiarity, and if we take the necessity of logarithmic transformation of these variables into account, we obtain a new diagram that is more specific with respect to our particular case:



In contrast to models from previous studies, which considered purely linguistic relationships, here we need to remember that the range of values of the variable familiarity has a lower and an upper limit. Whereas the linguistic variable frequency has only a lower limit of $x = 1$, the familiarity measure has an upper limit of $V = 700$ in theory, but of $V = 600$ in our practical data. For this reason we modify the model as follows:



L-max denotes the logarithm of the upper limit *V*. The operator *B* needs to be negative so that the structure of the model is in accordance with equation (4)

$$\ln y = \ln V - (\ln a + B \ln x) \tag{4}$$

or with the reverse transformation of (4) into the non-linear equation (5):

$$y = \frac{V}{Ax^B}. \tag{5}$$

With regard to the empirical test, we need to take into account the fact that large values of *x* (frequency), which can occur when very large corpora are used, may in practice lead to

division by zero errors. This is because of the exponent B, which quickly lets the inverse of x get so close to zero that, given the limited accuracy of standard computations, it may not be possible to distinguish it from zero. To avoid this problem we add 1 in the denominator which does not impair the validity of the model:

$$y = \frac{V}{1 + Ax^B}. \tag{6}$$

Testing the Model

The adaptation of the model (6) to the data of the Brown Corpus leads (with V being empirically determined to be 629) to the following values of our parameters: $A = 0.6923$, $B = -0.3649$. With a determination coefficient of $R^2 = 0.61$ this result does not at first glance look very convincing. However, as the variance of the familiarities is very high, this low value of R^2 is still in agreement with the model. Note that the variance is caused by discrepancies in the familiarity judgments of the test subjects. However, Figure 1 shows that the trend of the data is well predicted by the model.

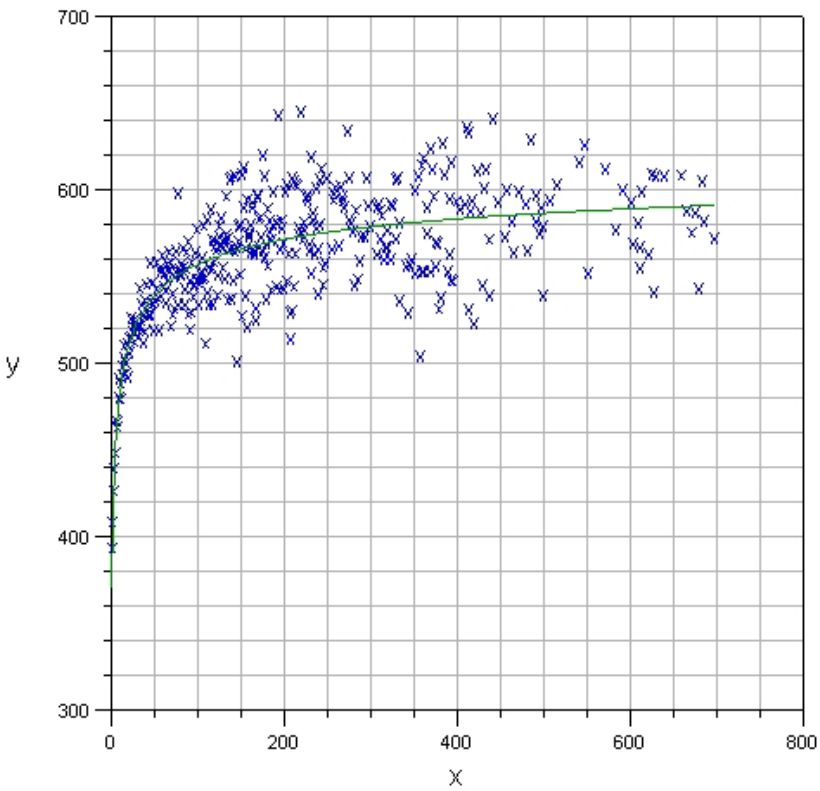


Figure 1. Fitting the model (6) to the data from the Brown Corpus: familiarity as a function of frequency

This is confirmed by an experiment where the data was smoothed using moving averages over an interval of 30 (see Figure 2). The empirical maximum of this curve is $V = 584$. The corresponding values of the parameters are $A = 2.880$, $B = -0.9273$, and $R^2 = 0.92$, which is a convincing result.

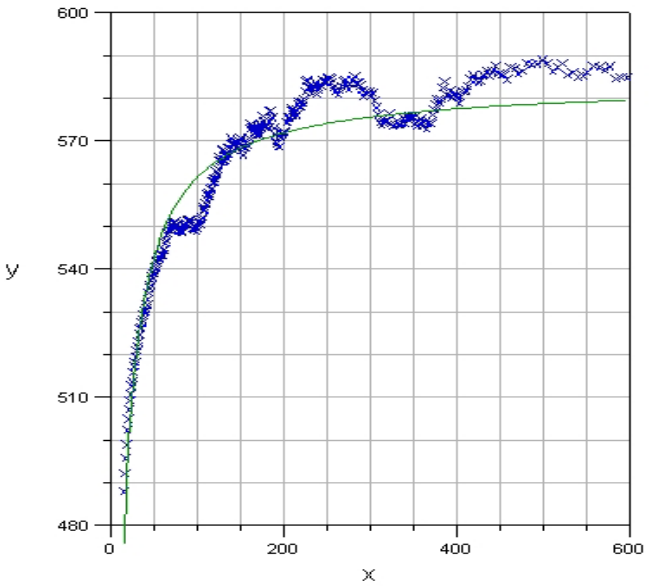


Figure 2. Fitting the model (6) to the smoothed data from the Brown Corpus: familiarity as a function of frequency

Another test of the model was conducted using frequency data from the BNC, which, as stated previously, is 100 times larger than the Brown Corpus. For the same reasons as before, moving averages with an interval size of 30 were again used. From these data we obtained, with a V of 632, the following parameters, which indicate an excellent fit: A = 3.11, B = -0.3428, and R^2 = 0.98 (see Figure 3).

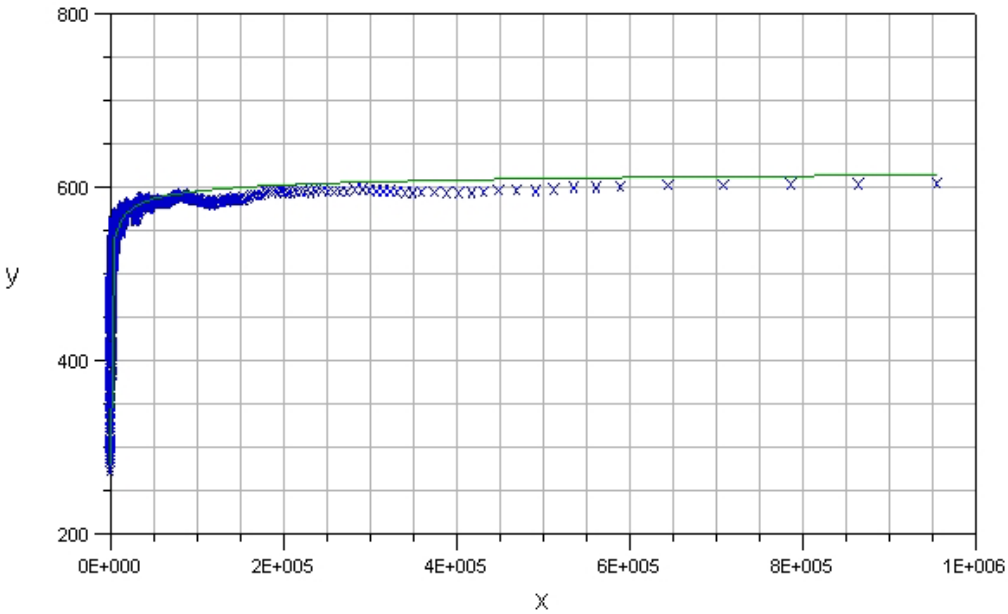


Figure 3. Fitting the model (6) to the smoothed data from the BNC: familiarity as a function of frequency

Summary and Prospects

Previous studies dealing with the relationship between word frequency and word familiarity judgments were usually based on a correlational analysis, which is the standard procedure in psychology in such cases. However, in this way only the linear component of a relationship can be taken into account, which is a clear drawback. By contrast, the present study shows, for two different corpora, a convincing functional relationship which takes into account the substantial non-linearity depicted in Figures 1 to 3. This means that predictions derived from the new model should be a considerable improvement over the predictions of previous models. It would be of interest to confirm whether the functional relationship discovered here holds true for languages other than English. A problem is that most familiarity norms were compiled for English, with little data available for other languages.

Acknowledgment

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Glottometrics 15, 2007, 71-81

Writer´s view of text generation

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Gabriel Altmann, Lüdenscheid

Abstract: Generally, a "writer's view", defined by the angle between the ends of the word rank-frequency distribution, as seen from the *h*-point, should be limited in the interval [π/2, π]. However, as shown in the present paper with 176 texts from 20 languages, actually the lower limit appears to be the golden number φ = 1.618... , rather than π/2 = 1.57...

Keywords: h-point, rank-frequency distributions, golden section

The writer of a text abides by some mechanisms of writing. Writing and speaking is a human activity performed according to some rules, habits or laws. Some of the mechanisms are conscious, other ones are unconscious, the writers need not even be aware of their existence. What is conscious, is the given language, its grammar, the contents of the text, the approximate length of the text and, after some thinking, the order of events in which the narrative must be presented, etc. The writer can control consciously the sentence length, the choice of words and some other properties, but he cannot control consciously everything. Some of the unconscious processes may sometimes become conscious, especially when one speaks an artificially learned language. But even in a foreign language we must suppose the existence of unconscious control of different processes.

Here we shall examine only the process of increasing word frequencies in text and building the rank-frequency distribution. As the text increases in length, new words are added occurring at first just once (new types), or some words are repeated getting higher frequency of occurrence. Predictions about a new occurrence of a certain word can be made only probabilistically and are not very reliable. While both the words at lower ranks continuously increase their frequency and new words (*hapax legomena*) are added, the beginning of the frequency curve increases vertically and the tail of the curve increases horizontally. Besides, the words at not extreme ranks steadily change their (rank) positions, thus the frequency curve seems to be in a steady flux. Nevertheless, there are some more solid entities in rank-frequencies of words conserving their properties in spite of the steady motion accompanying the increase of text. We mention here the distribution itself – being of Zipfian type or its generalizations; Ord's criteria – being characteristic for languages; and the type-token curves, etc. (cf. Popescu et al. 2007). Other properties arise through self-organization, e.g. building of binary runs of F-segments in long sentences (cf. Uhlířová 2007).

Here we shall report a peculiar convergence property of the rank-frequency distribution, $f = f(r)$, by observing the development of the so-called *h*-point during the increase of text length. As is known (s. Popescu 2006; Popescu, Altmann 2006; Popescu et al. 2007), the *h*-point is defined as the point at which $r = f(r)$, i.e. where the rank is equal to frequency. As a rule, the actual rank-frequency distributions are discrete and this is why sometimes the *h*-point is situated between two ranks; but its exact value can easily be computed in different ways. In graphical terms, the fitted graph of $f(r)$ has the *h*-point in common with the line $y = x$. An analytical method consists in the best fitting with a Zipf distribution, $f(r) = c / r^a$ (with a and

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c constants), or with a Mandelbrot distribution $f(r) = c/(b+r)^a$ (with a, b, and c constants), from which we get $h_Z = c^{1/(1+a)}$ or, respectively the equation $h_M = c/(b+h_M)^a$. Obviously, the h-point of actual discrete distributions is closely related to the mathematical fixed point of continuous functions, and is defined by the same rule $r = f(r)$.

Writing the text, the h-point automatically increases with increasing N. However, it has been shown that the ratio $a = N/h^2$ is very stable for languages and depends on their degree of analyticity/syntheticity.

With the first written words, the h-point is 1 and it remains so until one of the written words is repeated (Fig. 1). This usually happens after two-three sentences. The first repeated word creates a triangle between the points $P_1(V, 1)$ – V being the vocabulary of the text – $P_2(1, f_1)$ – f_1 being the frequency of the most frequent word – and $P_3(h, h)$, which begins to increase (Fig. 2). The h-point increases with increasing N (Fig. 3 and 4) but we suppose that something in this growth remains constant and is subconsciously controlled by the writer. Imagine that the writer "sits" at the h-point and controls the consistent development of the upper part of the rank-frequency curve (between f_1 and h) and its lower part (between h and V). One can suppose that a "normal" text arises if the angle of the triangle does not surpass a minimum and a maximum value. Perhaps there is a general constant or different constants for individual languages and genres, but we shall study the problem generally.

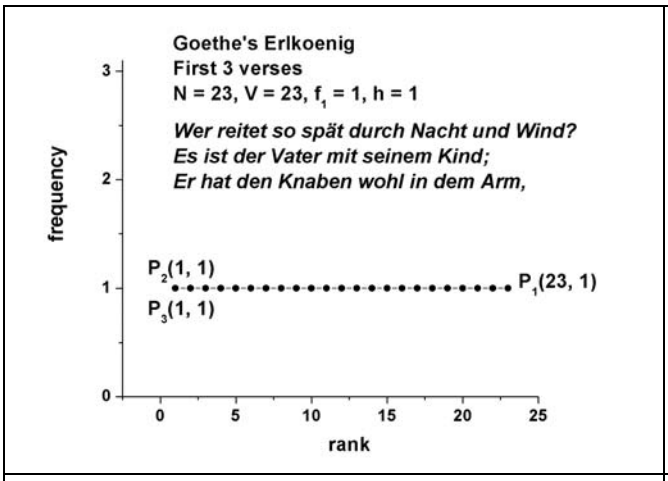

Figure 1

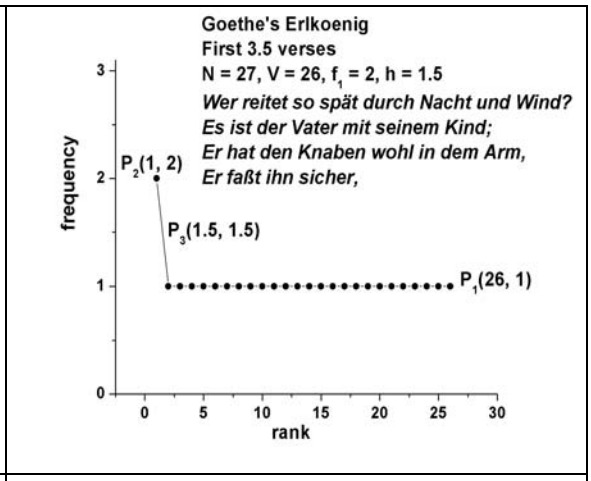

Figure 2

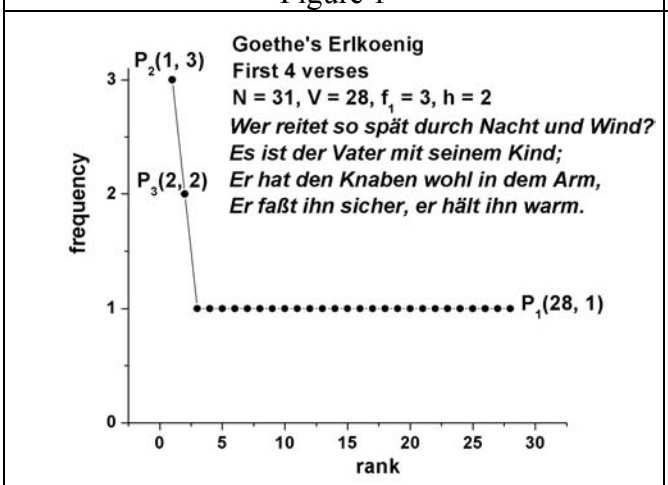

Figure 3

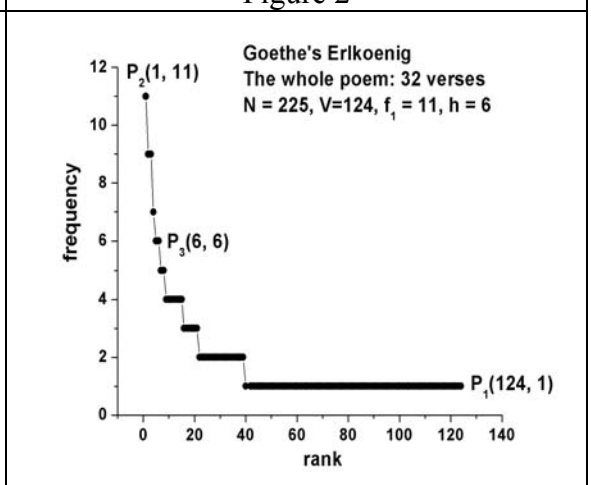

Figure 4

Figures 1 to 4 (Figures 2 to 4 show the developing h-point)

Let us consider a word rank-frequency distribution represented, as usually (see Figure 4), in a Cartesian *Oxy* system of coordinates, *Ox* for ranks (with the maximum value V at the point P_1) and *Oy* for frequencies (with the maximum value f_1 at the point P_2). Let us also have the *h*-point located at the point P_3. To summarize, we have the three characteristic points of the distribution given by their coordinates as follows:

$P_1\ (V, 1)$
$P_2\ (1, f_1)$
$P_3\ (h, h)$

We will consider the angle seen from the *h*-point P_3 and formed by the directions towards the distribution end P_1 and top P_2. In other words, we want an expression of the angle between the following two vectors:

(a) the vector **a** (a_x, a_y), directed from the *h*-point P_3 towards the distribution top P_2, having the components

$a_x = -h$
$a_y = f_1 - h$

and the absolute value (modulus)

(1) $a = (a_x^2 + a_y^2)^{1/2} = (h^2 + (f_1 - h)^2)^{1/2}$

(b) the vector **b** (b_x, b_y), directed from the *h*-point P_3 towards the distribution end P_1, having the components

$b_x = V - h$
$b_y = -h$

and the absolute value (modulus)

(2) $b = (b_x^2 + b_y^2)^{1/2} = ((V - h)^2 + h^2)^{1/2}$

In order to get the angle between the above vectors ***a*** and ***b*** we shall use the well known dot product formula of vector calculus

(3) $\cos\alpha = \boldsymbol{a.b}/ab$

where

(4) $\boldsymbol{a.b} = a_x b_x + a_y b_y$

that is

(5) $$\cos\alpha = \frac{a_x b_x + a_y b_y}{[(a_x^2 + a_y^2)^{1/2}][(b_x^2 + b_y^2)^{1/2}]}$$

which, in our particular case, becomes

(6) $$\cos\alpha = \frac{-[h(f_1 - h) + h(V - h)]}{[h^2 + (f_1 - h)^2]^{1/2}[h^2 + (V - h)^2]^{1/2}}$$

As expected, all numerical cosine values are negative because the corresponding angles are located in the second quadrant (from π/2 to π radians, respectively from 90 to 180 degrees). Let us illustrate the computation for a text having length N = 761, V = 400, h =10 and f_1 = 40. Inserting these numbers in (6) we obtain

$$\cos\alpha = \frac{-[10(40-10)+10(400-10)]}{[10^2+(40-10)^2]^{1/2}[10^2+(400-10)^2]^{1/2}} = -0.3404$$

hence **α** = 1.9182 radians.

In order to study the behavior of the angle **α** in radians, which we call "writer´s view", we used the data published in Popescu et al. (2007) containing 176 texts in 20 languages as presented in Table 1. Here B = Bulgarian, Cz = Czech, E = English, G = German, H = Hungarian, Hw = Hawaiian, In = Indonesian, I = Italian, Kn = Kannada, Lt = Latin, Lk = Lakota, M = Maori, Mq = Marquesan, Mr = Marathi, R = Romanian, Rt = Rarotongan, Ru = Russian, Sl = Slovenian, Sm = Samoan, T = Tagalog. Ordering the table according to increasing text length (N) we obtained a surprising result: The angle called "writer´s view" converges to the golden section known from several arts, different domains of aesthetics and sciences, namely to

$$\varphi = \frac{1+\sqrt{5}}{2} = 1.6180\ldots,$$

as can be seen in Table 1 and in Figure 5.

Table 1
The development of "writer's view" in increasing text size (176 texts from 20 languages)

Text ID	N	V	f(1)	h	cos α	α rad
G 14	184	129	10	5	-0.735	2.3965
Lk 04	219	116	18	6	-0.4953	2.0889
G 17	225	124	11	6	-0.7997	2.4977
G 12	251	169	14	6	-0.629	2.2511
G 07	263	169	17	5	-0.4126	1.9961
B 08	268	179	10	6	-0.8508	2.5883
Hw 01	282	104	19	7	-0.5647	2.1709
In 04	343	213	11	5	-0.6585	2.2896
Lk 01	345	174	20	8	-0.5941	2.207
In 03	347	194	14	6	-0.6252	2.2462
B 02	352	201	13	8	-0.8692	2.6244
In 02	373	209	18	7	-0.5658	2.1722
In 01	376	221	16	6	-0.5382	2.1391
H 03	403	291	48	4	-0.1044	1.6754
B 05	406	238	19	7	-0.5298	2.1292
H 05	413	290	32	6	-0.2454	1.8187
In 05	414	188	16	8	-0.7378	2.4006

Sm 05	447	124	39	11	-0.4541	2.0422
Mq 02	457	150	42	10	-0.3655	1.945
Cz 09	460	259	30	6	-0.2655	1.8395
G 13	460	253	19	8	-0.6143	2.2322
G 11	468	297	18	7	-0.5571	2.1617
G 10	480	301	18	7	-0.5568	2.1613
B 04	483	286	21	8	-0.5484	2.1512
G 03	500	281	33	8	-0.3325	1.9098
B 03	515	285	15	9	-0.8497	2.5862
G 16	518	292	16	8	-0.7267	2.3844
Cz 04	522	323	27	7	-0.3512	1.9296
G 04	545	269	32	8	-0.3451	1.9232
G 06	545	326	30	8	-0.3653	1.9447
B 09	550	313	20	9	-0.6559	2.2861
B 10	556	317	26	7	-0.3668	1.9464
B 07	557	324	19	8	-0.6085	2.2249
G 05	559	332	30	8	-0.3648	1.9443
G 15	593	378	16	8	-0.7222	2.3778
Sm 03	617	140	45	13	-0.4688	2.0587
Rt 04	625	181	49	11	-0.3395	1.9172
G 09	653	379	30	9	-0.4162	2.0000
Cz 08	677	389	31	8	-0.3483	1.9265
B 06	687	388	28	9	-0.4494	2.0369
R 06	695	432	30	10	-0.4683	2.0581
Sm 04	736	153	78	12	-0.2617	1.8356
Ru 01	753	422	31	8	-0.3467	1.9249
Sl 01	756	457	47	9	-0.2500	1.8234
B 01	761	400	40	10	-0.3404	1.9182
Lk 03	809	272	62	12	-0.2780	1.8525
Lt 06	829	609	19	7	-0.5139	2.1105
G 02	845	361	48	9	-0.2497	1.8232
Rt 02	845	214	69	13	-0.2885	1.8635
I 03	854	483	64	10	-0.2028	1.775
Rt 03	892	207	66	13	-0.3026	1.8782
H 04	936	609	76	7	-0.1125	1.6835
G 08	965	509	39	11	-0.3861	1.9672
Rt 01	968	223	111	14	-0.2087	1.781
Cz 02	984	543	56	11	-0.2575	1.8312
Cz 05	999	556	84	9	-0.1355	1.7067
R 05	1032	567	46	11	-0.3186	1.8951
Cz 01	1044	638	58	9	-0.1947	1.7668

Kn 004	1050	720	23	7	-0.4098	1.993
Rt 05	1059	197	74	15	-0.3252	1.902
G 01	1095	530	83	12	-0.1894	1.7614
I 05	1129	512	42	12	-0.3936	1.9753
Cz 10	1156	638	50	11	-0.2883	1.8632
Sm 02	1171	222	103	15	-0.2388	1.812
M 02	1175	277	127	15	-0.1892	1.7611
R 03	1264	719	65	12	-0.2373	1.8104
R 04	1284	729	49	10	-0.2618	1.8357
H 02	1288	789	130	8	-0.0757	1.6465
M 04	1289	326	137	15	-0.1697	1.7413
Kn 013	1302	807	35	10	-0.383	1.9638
Lt 05	1354	909	33	8	-0.3132	1.8894
Sl 02	1371	603	66	13	-0.2596	1.8334
M 03	1434	277	128	17	-0.2156	1.7881
Sm 01	1487	267	159	17	-0.186	1.7578
Mq 03	1509	301	218	14	-0.117	1.6881
T 01	1551	611	89	14	-0.2065	1.7788
Cz 06	1612	840	106	13	-0.154	1.7254
Lk 02	1633	479	124	17	-0.1931	1.7651
R 01	1738	843	62	14	-0.2962	1.8715
T 02	1827	720	107	15	-0.1819	1.7537
Hw 02	1829	257	121	21	-0.2914	1.8665
Mr 035	1862	1115	29	11	-0.5299	2.1293
Sl 03	1966	907	102	13	-0.1589	1.7304
Cz 07	2014	862	134	15	-0.1426	1.7139
H 01	2044	1079	225	12	-0.0675	1.6383
T 03	2054	645	128	19	-0.2015	1.7737
M 01	2062	398	152	18	-0.1799	1.7517
R 02	2279	1179	110	16	-0.1813	1.7531
E 01	2330	939	126	16	-0.1611	1.7326
Mq 01	2330	289	247	22	-0.1787	1.7505
Ru 02	2595	1240	138	16	-0.143	1.7143
Cz 03	2858	1274	182	19	-0.1308	1.702
Mr 002	2922	1186	73	18	-0.3256	1.9025
Mr 149	2946	1547	47	12	-0.3317	1.9089
E 02	2971	1017	168	22	-0.1708	1.7425
Mr 001	2998	1555	75	14	-0.2325	1.8055
Mr 007	3162	1262	80	16	-0.255	1.8286
Kn 003	3188	1833	74	13	-0.2154	1.7879
E 03	3247	1001	229	19	-0.1094	1.6804

I 04	3258	1237	118	21	-0.2284	1.8013
Lt 01	3311	2211	133	12	-0.1041	1.6751
Mr 293	3337	2006	41	13	-0.427	2.012
Mr 043	3356	1962	44	16	-0.5033	2.0982
Mr 150	3372	1523	64	16	-0.3263	1.9032
Mr 029	3424	1412	28	17	-0.8461	2.5795
Mr 034	3489	1865	40	17	-0.6018	2.2165
Sl 04	3491	1102	328	21	-0.0876	1.6585
Hw 03	3507	521	277	26	-0.1551	1.7265
Mr 052	3549	1628	89	17	-0.24	1.8132
Mr 154	3601	1719	68	17	-0.3257	1.9025
M 05	3620	514	234	26	-0.1767	1.7484
Mr 016	3642	1831	63	18	-0.3806	1.9612
Mr 006	3735	1503	120	19	-0.1974	1.7695
Mr 294	3825	1931	85	17	-0.2511	1.8247
Mr 296	3836	1970	92	18	-0.2453	1.8186
Mr 021	3846	1793	58	20	-0.4757	2.0666
Ru 03	3853	1792	144	21	-0.18	1.7518
Mr 020	3943	1825	62	19	-0.4138	1.9974
Mr 291	3954	1957	86	18	-0.2649	1.8389
Lt 02	4010	2334	190	18	-0.1118	1.6828
Mr 290	4025	2319	42	17	-0.5684	2.1754
Mr 288	4060	2079	84	17	-0.2539	1.8275
Mr 018	4062	1788	126	20	-0.1965	1.7686
Mr 038	4078	1607	66	20	-0.4103	1.9935
Mr 022	4099	1703	142	21	-0.1833	1.7551
Mr 027	4128	1400	92	21	-0.2982	1.8736
Mr 003	4140	1731	68	20	-0.3954	1.9773
Kn 012	4141	1842	58	19	-0.4473	2.0346
Mr 023	4142	1872	72	20	-0.369	1.9488
Mr 026	4146	2038	84	19	-0.2896	1.8646
Mr 017	4170	1853	67	19	-0.3777	1.9581
Mr 046	4186	1458	68	20	-0.3974	1.9795
Mr 036	4205	2070	96	19	-0.2486	1.822
Mr 024	4255	1731	80	20	-0.3273	1.9042
Lt 04	4285	1910	99	20	-0.2557	1.8293
Kn 017	4316	2122	122	18	-0.179	1.7507
Mr 033	4339	2217	71	19	-0.3513	1.9298
Kn 011	4541	2516	63	17	-0.353	1.9316
Mr 297	4605	2278	88	18	-0.2567	1.8305
E 04	4622	1232	366	23	-0.0859	1.6568

Mr 015	4693	1947	136	21	-0.1904	1.7623
Kn 016	4735	2356	93	18	-0.2409	1.814
E 05	4760	1495	297	26	-0.1131	1.6841
Mr 292	4765	2197	88	19	-0.2739	1.8482
Mr 289	4831	2312	112	19	-0.2083	1.7806
Mr 151	4843	1702	192	23	-0.1484	1.7198
E 06	4862	1176	460	24	-0.0757	1.6466
Kn 005	4869	2477	101	16	-0.1914	1.7634
Mr 295	4895	2322	97	20	-0.2598	1.8336
Lt 03	4931	2703	103	19	-0.2275	1.8003
Mr 005	4957	2029	172	19	-0.1326	1.7038
E 07	5004	1597	237	25	-0.1329	1.7041
E 08	5083	985	466	26	-0.086	1.6569
Mr 031	5105	2617	91	21	-0.2951	1.8703
Mr 028	5191	2386	86	23	-0.3521	1.9306
Mr 032	5195	2382	98	23	-0.3025	1.8781
Mr 040	5218	2877	81	21	-0.3373	1.9148
Kn 006	5231	2433	74	20	-0.3551	1.9338
Mr 010	5394	1650	217	27	-0.1571	1.7286
Mr 008	5477	1807	190	27	-0.1784	1.7501
Mr 030	5504	2911	86	20	-0.2966	1.8719
Sl 05	5588	2223	193	25	-0.1584	1.7299
E 09	5701	1574	342	29	-0.1109	1.682
Ru 04	6025	2536	228	25	-0.1321	1.7033
I 02	6064	2203	257	25	-0.1185	1.6896
Mr 009	6206	2387	93	26	-0.372	1.952
E 10	6246	1333	546	28	-0.0754	1.6463
Mr 004	6304	2451	314	24	-0.0923	1.6633
Hw 05	7620	680	416	38	-0.1586	1.7301
Hw 04	7892	744	535	38	-0.1297	1.7009
E 11	8193	1669	622	32	-0.0737	1.6445
E 12	9088	1825	617	39	-0.0891	1.66
E 13	11265	1659	780	41	-0.0807	1.6516
I 01	11760	3667	388	37	-0.115	1.686
Hw 06	12356	1039	901	44	-0.0953	1.6663
Ru 05	17205	6073	701	41	-0.0688	1.6396

In Figure 5 we see that some texts approximate this value even if they are short, but in any case, long texts tend to it. For instance, the latter case is best demonstrated by Goethe's Faust as shown in the table below

Text	N	V	f(1)	h	cos α	α rad
Faust 1.	30625	6303	918	64	-0.0850	1.6559
Faust 1. and 2.	75050	13341	2089	90	-0.0518	1.6226

This is, perhaps, the way how to attain harmonic proportions in texts. It may be expected that further texts with $N \approx 2500$ had filled the gap in Figure 5 between the two branches of the points following most probably a power curve.

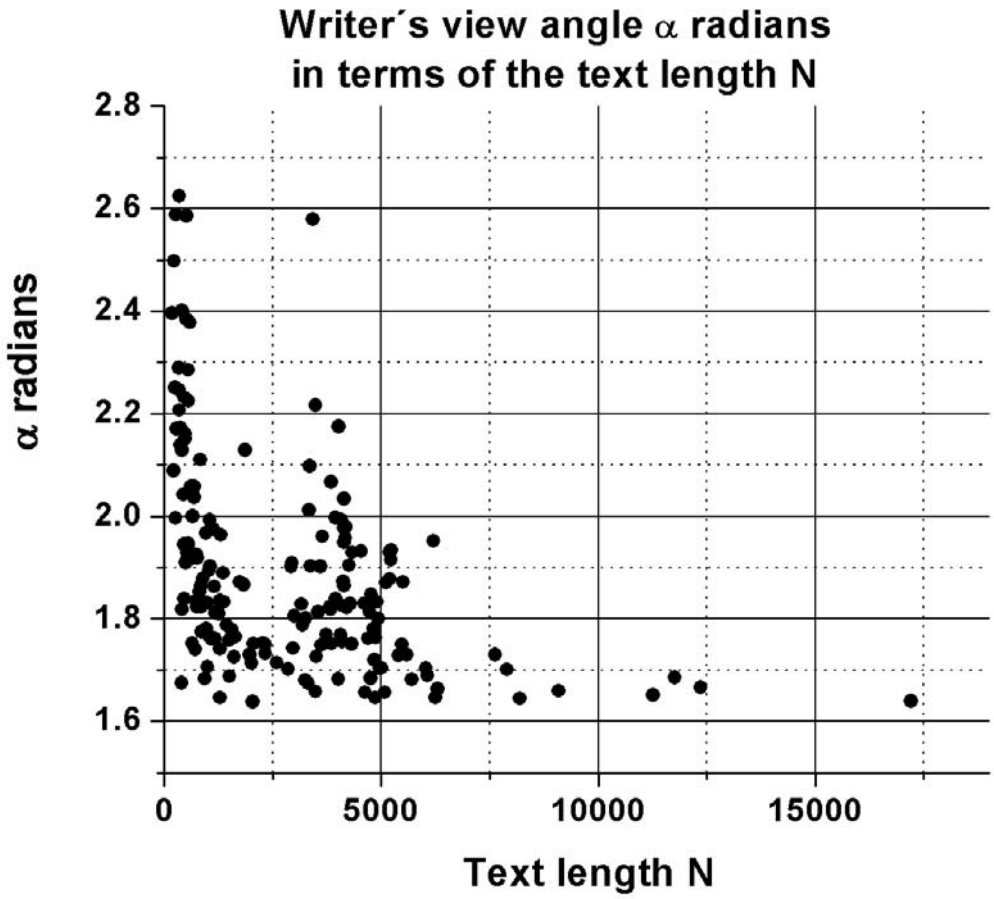

Figure 5. Illustrating the dependence of the "writer's view" α radians in terms of the text length N for 176 texts in 20 languages. All data lay within the interval $\varphi = 1.618...$ to $\pi = 3.14...$

The theoretical upper angle is $\pi = 3.14...$, however, the actual boundary is not precisely known. Many shorter texts (e.g. poems) must be analysed in order to venture a well grounded statement. One example is given in continuation with cumulative sequences from Goethe's Erlkönig indicating for the corresponding upper boundary an average value of about 3 (Table 2).

Though we believe that the golden section is present in texts in some way and can be found by different methods, the fact that the rank-frequency distribution and its *h*-point can make it at least visible, is a good argument for further study of word frequencies.

Table 2
Development of α rad in Goethe´s Erlkönig

Goethe's Erlkönig	N	V	f(1)	h	cos α	α rad
first 10 words	10	10	1	1	-0.9939	3.0309
first 20 words	20	20	1	1	-0.9986	3.0890
first 30 words	30	27	3	2	-0.9272	2.7578
first 60 words	60	45	3	3	-0.9975	3.0703
first 100 words	100	69	4	4	-0.9981	3.0801
first 140 words	140	88	7	5	-0.9491	2.8213
first 220 words	220	122	11	6	-0.8003	2.4985

The texts in Table 1 are all of moderate length, allowing us to suppose that they were written "in one go". It is known that several writers were able to write a book in one day. Practically, longer texts are mixtures of texts even if they were written by the same author. The smooth process of writing is interrupted in many places and a new "vocabulary regime" can distort all ratios (e.g. TTR, the **α** angle, the thematic concentration etc.). Hence their investigation is not very prolific. Nevertheless, we ventured an experiment and took some very long texts, even translations (which are on many grounds forbidden in linguistics) and brought them to a common statement about the mean of the α radian. As individual texts they have no expressiveness – because they are mixed – but representing a statistical sample they can tell us something about the unweighted mean of the sample. In Table 3 we show some randomly chosen well known mixtures. Though with some texts α rad is below 1.60, their unweighted average is 1.61. Though we do not consider this result as corroborating our hypothesis, it is nevertheless enlightening. The texts presented in Table 1 and 3 are shown in Figure 6 where the long "texts" are better differentiated.

Further research can help us to decide whether the convergence is caused also by language or genre and help us to decipher the form of the convergence. It can help us also to diagnose text mixtures.

Table 3
Mixed texts

Author		Text	N	V	f(1)	h	cos α	α rad
Goethe	German	Faust 1.	30625	6303	918	64	-0.08496	1.6559
Goethe	German	Faust 1. and 2.	75050	13341	2089	90	-0.05176	1.6226
Milton	English	Paradise Lost	79879	10211	3330	98	-0.03999	1.6108
The Evangelists	English tr.	The Gospels	83932	3501	5669	112	-0.05316	1.6240
Conan Doyle	English	Sherlock Holmes	104230	8324	5601	112	-0.03403	1.6048
Homer	English tr.	The Odyssey	117386	6800	5875	137	-0.04442	1.6152
Homer	English tr.	The Iliad	152455	7776	9945	150	-0.03497	1.6058
Moses	English tr.	The Pentateuch	156872	4797	13667	150	-0.04335	1.6142
The Bible	English tr.	New Testament	180573	6005	10976	160	-0.04215	1.6130
Dickens	English	Great Expectations	185104	11376	8139	161	-0.03453	1.6053
Dostoevsky	English tr.	Crime and Punishment	202853	10728	7768	174	-0.03938	1.6102

Joyce	English	Ulysses	263324	29457	14905	169	-0.01724	1.5880
Dickens	English	David Copperfield	360779	17225	13918	210	-0.02766	1.5985
Tolstoy	English tr.	War and Peace	561723	20094	34391	255	-0.02032	1.5911
The Bible	English tr.	Old Testament	610051	10751	52934	270	-0.03088	1.6017
The Bible	English tr.	Old & New Testament	790624	12698	63910	294	-0.02832	1.5991

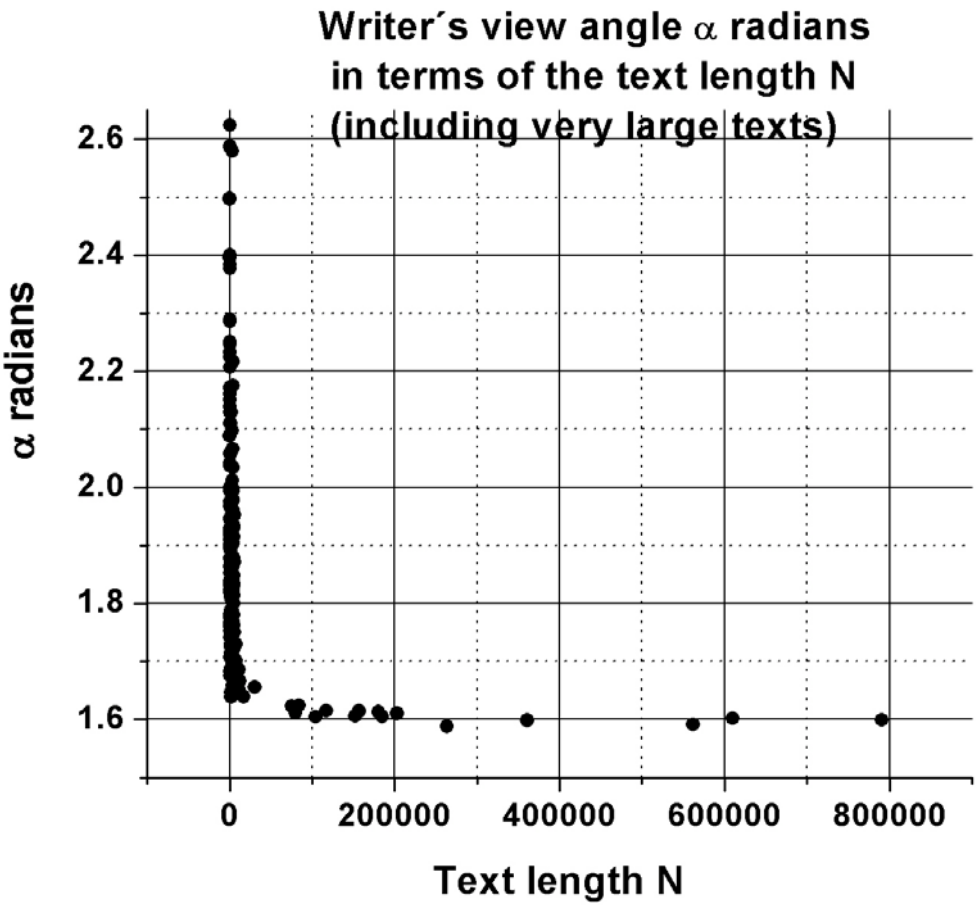

Figure 6. The course of α rad especially for very long texts

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On the systematic and system-based study of grapheme frequencies:
a re-analysis of German letter frequencies

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Abstract: This study looks at the theoretical modeling of letter frequencies. Based on recent findings demonstrating the negative hypergeometric function to be an adequate model, a re-analysis of German data reported by Best (2005) is conducted, concentrating on a detailed examination of parameter behavior. It is shown that all parameters of this distribution behave regularly, if the analysis is based on the system's inventory size, rather than on the class of items occurring in the given sample. Directions for future research are pointed out, particularly involving factors influencing parameter values.

Keywords: Grapheme frequency, German, negative hypergeometric distribution

Introduction

The frequency of letters and graphemes has recently been the focus of a growing level of interest. This holds particularly true with regard to various Slavic languages, which, in the last years, have been submitted to systematic studies, starting with Russian (Grzybek, Kelih 2003; Grzybek 2005; Grzybek, Kelih, Altmann 2004, 2005a), and including Slovak (Grzybek, Kelih, Altmann 2005b, 2007), Ukrainian (Grzybek, Kelih 2005b), Slovene (Grzybek, Kelih, Stadlober 2007).[1] These Slavic languages cover a spectrum of grapheme inventory size, from the minimal inventory of 25 letters (Slovene) to the maximum of 43 or 46 letters (Slovak)[2].

With regard to other languages, or language families, similarly systematic studies are not available, neither with regard to the material analyzed nor with regard to the theoretical models aiming to describe the frequencies and their distributions. Only for German grapheme frequencies are comparable studies available, from Karl-Heinz Best's (2005) study searching for regularities in the frequency behavior of letters and other characters. Best (2005: 9) starts from the assumption that, for German, there are only relatively sparse data which, furthermore, are quite obsolete and therefore give rise to the question of whether "they are still representative for contemporary circumstances". Since, additionally, these data are based on the analysis of heterogeneous corpus material, rather than on individual texts, Best (2005: 11) has pursued the question of whether "there is a theoretically motivated model which might be adequate to represent empirical data from rank frequency distributions of letters and other characters".

In this text, Best's specific data shall be submitted to an elaborating re-analysis. Before going into details as to Best's data, it seems reasonable, however, to briefly summarize the general framework of the overall problem.

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[1] For each of these languages, series of 30 samples have been systematically analyzed, partly controlling authorship, text type, and homogeneity of texts (text segments, text cumulations, text mixtures, etc.) as possible influencing factors.

[2] The difference in the Slovak inventory size depends on whether the three digraphs DZ, DŽ, CH are treated as separate inventory units or not; Grzybek, Kelih & Altmann (2005b) and Grzybek, Kelih & Altmann (2007) have studied both alternatives separately.

1. The negative hypergeometric distribution as a rank frequency model

Studies of rank frequencies focus on the proportion of the most frequent unit as compared to the second, third, etc. one, that is, on the overall relation between the individual frequencies. The objective of this approach is the theoretical modeling of such a rank frequency distribution, searching for a mathematical formalization of the distances between the individual occurrences: transforming the initial raw data into a ranked (usually decreasing) order, and connecting the individual data points, usually, a particular declining (hyperbolic) curve is obtained, rather than a linear decrease. It is the mathematical modeling of this curve which is at the center of this field of research, to see whether or not if the frequencies (or rather, the shape of their specific decline) is similar across different samples.

At closer sight, graphemes and their rank frequency distributions represent a discrete system, not a continuous curve. Since we are therefore rather concerned with two neighboring classes, it seems reasonable to search for an adequate discrete probability distribution, rather than for a continuous function; this has other advantages, too, which need not be mentioned in detail here (see Grzybek, Kelih 2003). In this context, referring to the theoretical framework of synergetic linguistics, we are faced with the generally accepted assumption that the probability of a given class x (or rank r) behaves itself proportionally to the neighboring lower class, i.e., x-1, or r-1 (see Altmann, Köhler 1996). Based on this general approach we formulate the difference equation

(1) $$P_x = g(x)P_{x-1}$$

the concrete solution of which depends on the concrete form of the function *g(x)*. As to the frequency of various linguistic units, relatively simple functions have repeatedly been shown to yield convincing results, even with $g(x)$ being represented by simple rational functions. In attempting to qualitatively interpret these functions, the "speaker's forces" were assumed to be represented in the function's numerator, the regulating "hearer's forces", as compared to this, in its denominator. This approach has recently been significantly generalized by Wimmer, Altmann (2005, 2006); for linguistic questions, various distribution models, among others, can be derived from the central equation:

(2) $$P_x = \left(1 + a_0 + \frac{a_1}{(x+b_1)^{c_1}} + \frac{a_2}{(x+b_2)^{c_2}}\right)P_{x-1}$$

One of these models is the negative hypergeometric distribution (Wimmer, Altmann 1999: 465ff.), which, in all above-mentioned studies, has turned out to be an adequate model for both the Slavic languages and German. After re-parametrization, from (2) the recursion formula (3) is obtained

(3) $$P_x = \frac{(M+x-1)(n-x+1)}{x\left(K-M+n-x\right)}P_{x-1}\ ,$$

from which the negative hypergeometric distribution results:

(4) $$P_x = \frac{\binom{M+x-1}{x}\binom{K-M+n-x-1}{n-x}}{\binom{K+n-1}{n}} \qquad x = 0,1,2,\ldots,n, \quad K > M > 0;\ n \in \{1,2,\ldots\}$$

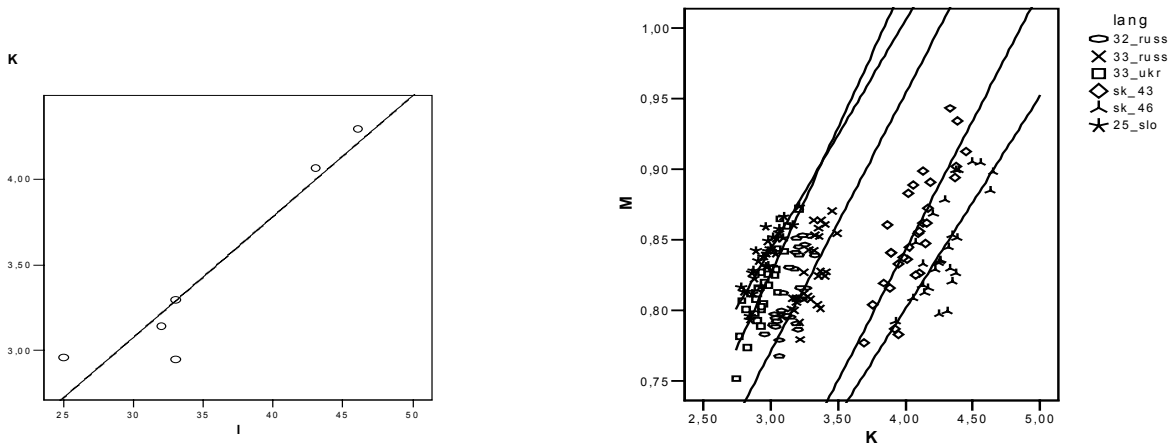
For ranking purposes, this distribution is conventionally shifted one step to the right, thus yielding the 1-displaced negative hypergeometric distribution (5):

$$(5) \qquad P_x = \frac{\binom{M+x-2}{x-1}\binom{K-M+n-x}{n-x+1}}{\binom{K+n-1}{n}} \qquad x = 1, 2, \ldots, n+1 \qquad K > M > 0;\ n \in \{1, 2, \ldots\}$$

2. From model to parameter interpretation

The adequacy of the distribution model (5) for letter frequencies has been repeatedly demonstrated in the above-mentioned recent research, for Slavic languages as well as for German. In the case of the Slavic languages, the adequacy of other models previously discussed in linguistics has been also tested in a systematic way. Only the negative hypergeometric distribution has turned out to be an overall valid model. Furthermore, the analyses of Slavic letter frequencies have yielded the first insight into the systematic behavior of parameters *K* and *M*, thus allowing for some hypotheses as to their qualitative interpretation (on this question, see Grzybek, Kelih 2005c; Grzybek et al. 2006). Yet attempts at general parameter interpretation are in their infancy; to achieve this goal, further studies, examining more languages, are needed. From what we know, it seems that three factors have particular impact on the parameter values: 1) inventory size, 2) relative frequency of the first rank, and 3) mean value of the given distribution.

It seems that inventory size is the foremost influence on the overall system behavior. Figures 1a and 1b illustrate the general tendency as it emerges from the analysis of six sample series from Slovene ($I = 25$), Russian ($I = 32$, or $I = 33$, respectively)[3], Ukrainian ($I = 33$) and Slovak ($I = 43$, or $I = 46$, respectively)[4]: Figure 1a shows the dependency of parameter *K* on inventory size *I*, based on the parameter mean values of each language; with a correlation coefficient of $r = 0.94$ the linear dependence turns out to be significant ($p = 0.005$). Figure 1b shows the correlation between parameters *K* and *M*, which is not, however, relevant between languages, but rather within a given language.



(a) Correlation between *K* and *I* (b) Correlation between *K* and *M*

Figure 1. Parameter Behavior for six Slavic Sample Series

[3] The difference in the Russian inventory size depends on treating the letter ‚ё' as a separate letter in its own right or not (cf. Grzybek et al. 2005).

[4] As to the differences in Slovak inventory size, see fn. 1.

As shown by the graphs, the regression lines for the individual languages display a clear tendency to be parallel, which, in turn, can also be interpreted in terms of a dependency on inventory size. The regression lines follow the equation $y = b + ax$ (that is, in our case, $M = b + aK$); here, b is a constant determining the regression intercept, and a is the regression coefficient which determines the steepness for the rise or decline of the line. Introducing the intercept values of the individual languages into a regression model with inventory size I as the independent variable yields a highly significant correlation ($r = 0.96$, $p < 0.001$); Figure 2 illustrates this correlation.

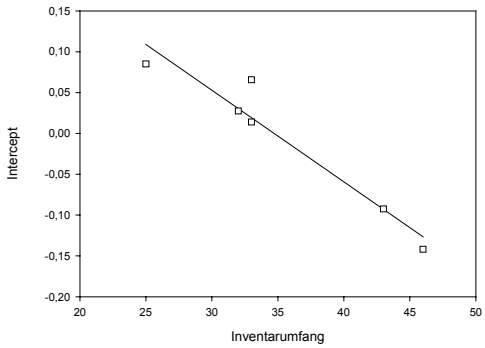


Figure 2. Correlation between the intercepts of the regression model and inventory size I for six Slavic sample series

So we are concerned, on the one hand, with an interlingual (linear) dependence of parameter K on inventory size I; and on the other hand, with a language-specific (linear) dependence of parameter M on K. For all the languages studied previously (Russian, Slovak, Slovene, Ukrainian), this situation can be traced back to an overall (linear) regression model, for which interlingual and language-specific principles can be distinguished (Grzybek et al. 2006).

The study of other languages has not yet reached this point; this holds also true for German, where the question of parameter interpretation has not yet been touched upon. Given this state of the art, the following re-analysis of the data presented by Best (2005) focuses on the systematic study of the parameter values obtained for the negative hypergeometric distribution.

2. Material

As mentioned above, Best (2005) provides a number of analyses of individual texts, in addition to corpus data; the resulting 14 data sets are characterized in Table 1:

Table 1
Text basis from Best (2005)

Nr.	Text	Nr.	Text
1	H. Pestalozzi: Hühner, Adler und Mäuse	**8**	F. Kafka: Der Prozeß
2	G.A. Bürger: Münchhausen	**9**	G. Vesper: Fugen
3	G.A. Bürger: Lenore	**10**	O. Jägersberg: Dazugehören
4	G. Büchner: Lenz	**11**	J. Joffe: Nach dem Bruderkrieg
5	G. Büchner: Hessischer Landbote	**12**	R. Hoppe: Das gierige Gehirn
6	K. May: Winnetou I	**13**	Schönpflug (1969)
7	F. Kafka: Die Verwandlung	**14**	K.H. Best: Wiss. Prosa

In Best's (2005) study, some of these texts have been analyzed twice: once taking into account "only" letters, and once including all occurring characters (such as blanks, apostrophes, dashes, etc.). Therefore, Best's study contains not only 14, but rather19 analyses. It goes without saying that taking into account these additional characters not only changes individual letters' relative frequency, but also the inventory size. Table 2 presents the relevant characteristics of the data: the column "Table" refers to Best's original numeration of tables, "Data Set" to the corresponding data set(s), partly analyzed twice. *N* indicates samples sizes, *I* is the corresponding inventory size. Table 2 also contains the values of parameter values *K* and *M* of the negative hypergeometric distribution, as given by Best (2005), as well as the corresponding fitting results, *C* being the determination coefficient calculated as X^2 / N.[5]

Table 2
Data sets from Best (2005)

Table	Data Set	*N*	*I*	*K*	*M*	X^2	*C*
1	1	675	27	3,0071	0,6847	17,63	0,0261
2	2	137476	30	3,4096	0,7385	1311,63	0,0095
3	3a	6215	27	3,1886	0,8109	45,99	0,0074
4	3b	7962	37	3,0934	0,6574	51,71	0,0065
5	4a	42608	30	3,4083	0,7289	425,28	0,0100
6	4b	53443	47	4,8953	0,6991	750,3	0,0140
7	5	21452	30	3,3167	0,7016	147,25	0,0069
8	6a	777368	32	3,7659	0,7610	9973,4	0,0128
9	6b	974506	48	4,7707	0,7033	12316,23	0,0126
10	7	99559	30	3,2877	0,7218	954,41	0,0096
11	8	361848	30	3,3554	0,7350	3437,86	0,0095
12	9a	6259	27	2,9541	0,7251	46,28	0,0074
13	9b	7555	31	3,0799	0,6859	92,00	0,0122
14	10	40977	30	3,4964	0,7775	269,79	0,0066
15	11	6091	30	3,4038	0,7372	35,42	0,0058
16	12a	20075	30	3,3278	0,7366	103,44	0,0052
17	12b	24977	53	6,4117	0,7414	305,04	0,0122
18	13	99984	29	3,2200	0,7265	462,28	0,0046
19	14	179922	30	3,2002	0,7254	1423,51	0,0079

4. Results

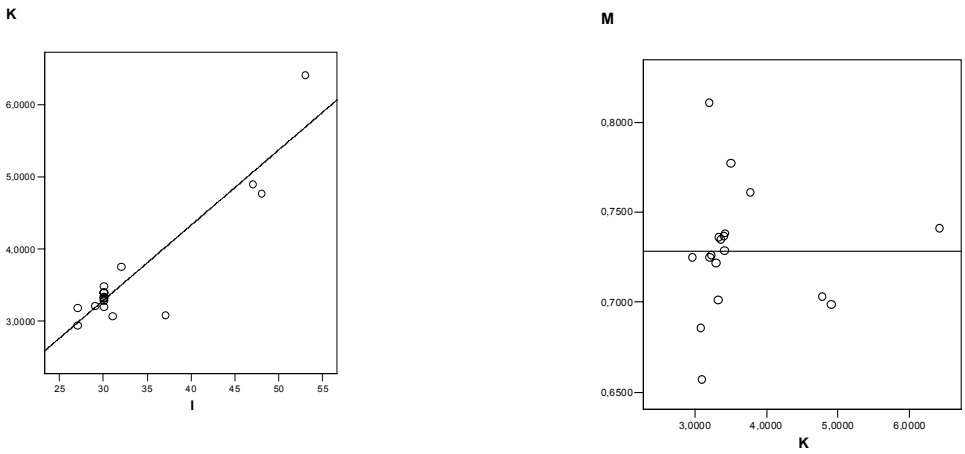
Without exception, the negative hypergeometric distribution turns out to be a very good model: With the exception of the very first text (extremely short at 675 letters), the values of the discrepancy coefficients are in the interval of $0.0046 \leq C \leq 0.0140$ – thus proving the negative hypergeometric distribution indeed to be a good model.[6]

[5] Interpreting the goodness of fit with reference to the X^2 values would have to be based on $DF = I$-4 degrees of freedom. Since the X^2 value increases linearly with sample size, and in this case tends to yield significant results more quickly, linguistic studies concerned with large sample sizes rather use to refer to the discrepancy coefficient. By way of convention, a value of $C \leq 0.02$ is interpreted as indicating a good, a value of $C \leq 0.01$ a very good fit; the degrees of freedom are irrelevant, here.

[6] The fit is very good, for the first text, too, with a X^2 value of 17.63, with 22 degrees if freedom corresponding to $P = 0.73$; the extreme differences in sample sizes, however, ranging from 675 to 974506, allows for a comparison of the longer texts only; therefore text #1 is excluded from the following re-analyses.

As mentioned above, due to Best's specific design partly including not only letters, the inventory sizes vary significantly in the interval of $27 \leq I \leq 53$. In analogy to the tendency described above for Slavic languages, this corresponds to a relatively large range for parameters K and M, which are in the intervals of $2.95 \leq K \leq 6.41$, and $0.66 \leq M \leq 0.81$ respectively.[7] Table 2 presents the results in detail.

Figures 3a and 3b illustrate the relations between inventory size and parameter K, and between parameters K and M.



(a) Relation between K and I (b) Relation between K and M

Figure 3. Parameter Behavior for 18 German Samples (Data reported by Best 2005)

The significant ($r = 0.92$) correlation between K and I can clearly be seen; no specific relation can be detected, however, between parameters K and M. As opposed to the studies reported above that concentrated on Slavic languages, the results are thus far from easily interpretable, particularly because the parameter values obtained for K and M display no systematic behavior. As an explanation for this lack of systematic behavior, it seems reasonable to assume that it is due to the varying inventory size, as a consequence of the changing number of units submitted to analysis.

In consequence, for the sake of a consistent and unitary treatment of the data material reported by Best (2005), the latter shall be submitted to a comprehensive re-analysis concentrating on the analysis of letters, only, and excluding all other characters.

At closer examination, however, a problem comes into play, which is not discussed in Best's study and, as a consequence, not treated systematically. This problem concerns the unitary treatment of letters which do not occur in a given sample. Basically assuming an inventory size of $I = 30$ for German[8], Best (2005) confines the inventory size to $I = 27$ for those cases – such as, for instance, #1, #3, or #9 – where letters Q,X,Y do not occur. Similarly, sample #13 – where letter ß does not occur – is restricted to (and calculated as) inventory size $I = 29$. In other cases – e.g., #7 und #10, where there is no X or no Y – Best (2005) has allocated frequency $f_i = 0$ to these classes; as a consequence, the inventory size of these samples is $I = 30$, notwithstanding the fact that in the corresponding case, these letters are missing from the data material. Furthermore, Best (2005) assumes sample #6 has an inventory size of $I = 32$, given the fact that a number of foreign words with the letters É, Ñ occur in the material.

[7] Upper and lower borders of the 95% confidence interval vary significantly for parameter K as well (3.21 and 4.08); as compared to this, the confidence interval for M is much small with upper and lower borders of 0.71 and 0.75, respectively.

[8] This definition pays no attention to the distinction between lowercase and capital letters, considering Ä, Ö, Ü, ß as separate units in their own right.

As a consequence, parameter *n* of the negative hypergeometric distribution ranges from 26 (e.g., when letters Q, X, Y do not occur in a given sample), to 28 (when ß is not taken into consideration), to 29, in one case even to 31, since in this text (*Winnetou I* by Karl May) É and Ñ happen to occur and are considered to be elements of the inventory. Table 2 represents the results of the modified data structure of the individual texts, concentrating on letters only.

Table 2
Samples from Best (2005)

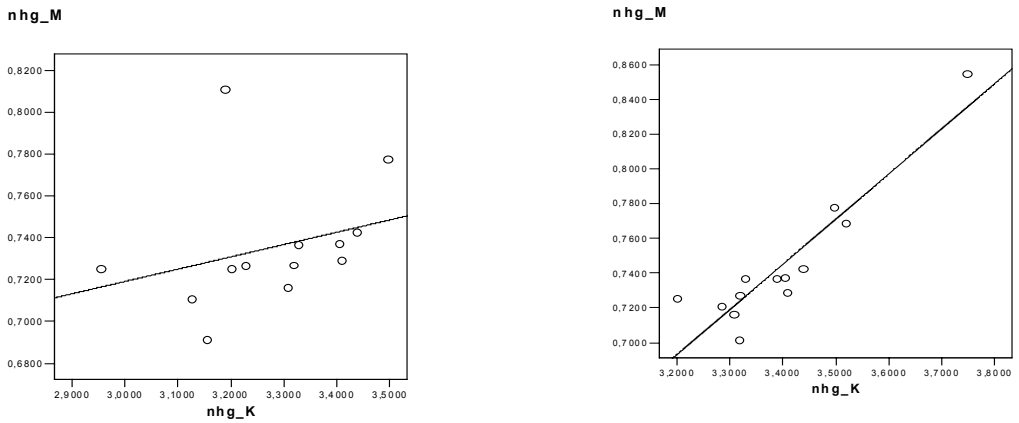
Nr.	Text	*N*	*I*	Basis
1	H. Pestalozzi: Hühner, Adler und Mäuse	675	27	Q,X,Y do not occur
2	G.A. Bürger: Münchhausen	137476	30	
3	G.A. Bürger: Lenore	6215	27	Q,X,Y do not occur
4	G. Büchner: Lenz	42608	30	
5	G. Büchner: Hessischer Landbote	21452	30	
6	K. May: Winnetou I	777361	32	É, Ñ; Ae -> Ä, Oe -> Ö, Ue -> Ü
7	F. Kafka: Die Verwandlung	99559	30	X = 0
8	F. Kafka: Der Prozeß	361848	30	
9	G. Vesper: Fugen	6259	27	Q,X,Y do not occur
10	O. Jägersberg: Dazugehören	40977	30	Y = 0
11	J. Joffe: Nach dem Bruderkrieg	6091	30	
12	R. Hoppe: Das gierige Gehirn	20075	30	
13	Schönpflug (1969)	99984	29	Without: ß
14	K.-H. Best: Wissenschaftliche Prosa	179922	30	

Achieving a systematic approach would consequently require a unitary treatment of the data to be analyzed. In principle, there are two options which shall both be pursued in our re-analysis:

1. the first alternative restricts the data sets to the analysis of those letters which occur in the relevant material, thus simply ignoring "missing" letters;
2. the second alternative assumes a given system to have a fixed inventory size and consequently integrates empty classes with frequency $f_i = 0$ into the data sets.

Whereas the first approach, which tolerates varying inventory sizes, thus meets the desires of a given "text", the second procedure is oriented to a system's needs. It will be interesting to compare the parameter behavior under these two conditions. As a matter of fact, this comparison must concentrate on the relation between parameters *K* and *M*, since the study of *K* and *I* makes no sense with fixed inventory size.

Figure 4 shows the differences for both conditions; although, after all, only 5 of the 13 samples have an altered inventory size, the differences are extremely clear. Figure 4a shows the effect of taking inventory size into consideration not on the basis of the given system, but on the observed realizations in each individual text: Under this condition, the linear trend to be observed in Figure 4a (with $I = 30$) is clearly disturbed; obviously the variation of *I* (directly reflected in parameter *n* of the negative hypergeometric distribution) also affects the parameter values *K* and *M* and thus disturbs, or even prevents, their behavior from being systematic and, as a consequence, amenable to a reasonable interpretation.



(a) *K* and *M* (*I* = varying) $r = 0.29$ ($p = 0.33$)

(b) *K* and *M* (*I* = 30) $r = 0.92$ ($p < 0.001$)

Figure 4. Correlation between parameters *K* and *M* (only letters)

In contrast to this, fixing the inventory size at $I = 30$, yields a clear correlation between parameters *K* and *M* ($r = 0.92$, $p < 0.001$) – cf. Figure 4b. The parameter values thus obtained are shown in Table 3, asterisks indicating diverging samples.

Table 3
Fitting results for two conditions

	I = 30				*I* = varying		
	K	*M*	*C*		*K*	*M*	*C*
1	3,3071	0,7163	0,0110	**1**	3,3071	0,7163	0,0110
***2**	3,7480	0,8546	0,0125	**2**	3,1886	0,8109	0,0074
3	3,4083	0,7289	0,0100	**3**	3,4083	0,7289	0,0100
***4**	3,3167	0,7016	0,0073	**4**	3,1549	0,6912	0,0058
5	3,4381	0,7427	0,0102	**5**	3,4381	0,7427	0,0102
***6**	3,2839	0,7210	0,0100	**6**	3,1257	0,7108	0,0084
7	3,3184	0,7269	0,0104	**7**	3,3184	0,7269	0,0104
***8**	3,5189	0,7688	0,0092	**8**	2,9541	0,7251	0,0074
9	3,4964	0,7775	0,0066	**9**	3,4964	0,7775	0,0066
10	3,4038	0,7372	0,0058	**10**	3,4038	0,7372	0,0058
11	3,3278	0,7366	0,0052	**11**	3,3278	0,7366	0,0052
***12**	3,3886	0,7366	0,0062	**12**	3,2268	0,7265	0,0046
13	3,2002	0,7254	0,0079	**13**	3,2002	0,7254	0,0079

This finding for the first time documents systematic parameter behavior not only for Slavic, but also for German letter frequencies.

The next step is to investigate whether this systematicity is eventually bought at the cost of worse fitting results. To be sure, a better fitting result alone should not be the decisive factor in favoring one of the two options – in any case, a procedure which can be theoretically motivated is preferable.

Yet, as the analysis shows, the fitting results are almost equally good under both condit-

ions; on average, the discrepancy coefficient is $C = 0.009$ for the "fixed condition", and thus, only slightly worse than the "system condition" with $C = 0.008$. Comparing the fitting results for both conditions with the non-parametric Mann-Whitney-U-Test, differences between both conditions turn out to be not significant ($z = -0.85$, $p = 0.42$). This result is reflected by Figure 5, which contains an error bar diagram for the C values.

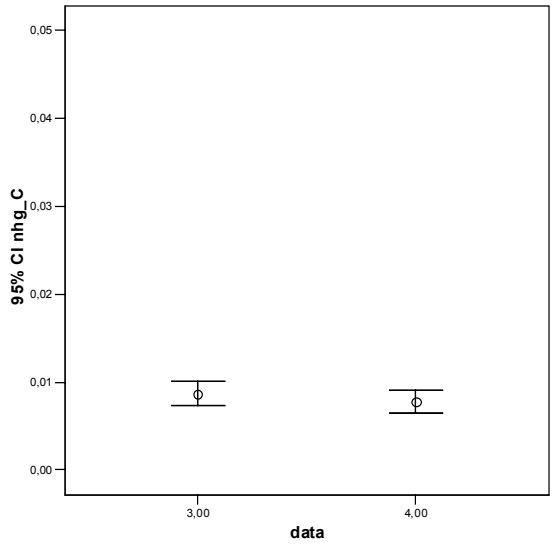


Figure 5. Error Bar Diagrams for C values

5. Summary and Perspectives

The results obtained in this study are a clear indication that the frequency of letters are regularly organized. Given the finding that the negative hypergeometric distribution has been shown to be an adequate model for both several Slavic languages and German, the present study provides additional evidence that the parameter behavior follows clear rules as well. As has been shown, however, this is only the case if the analysis is based on the system's inventory size rather than on the number of classes observed in the individual samples.

Additional interpretations of the concrete parameter values must be left for future research. As has been argued elsewhere (Grzybek 2007), it seems that, in addition to inventory size, it is the mean of the distribution on the one hand, and the relative frequency of the most frequent class on the other, which rule the system's overall behavior. It seems likely that estimating the parameter values of these statistical characteristics results in easy point estimations, which would explain the frequency behavior of letters; however, a definitive answer to this question must be left to the results of ongoing research.

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History of Quantitative Linguistics

Since a historiography of quantitative linguistics does not exist as yet, we shall present in this column short statements on researchers, ideas and findings of the past – usually forgotten – in order to establish a tradition and to complete our knowledge of history. Contributions are welcome and should be sent to Peter Grzybek, peter.grzybek@uni-graz.at.

XXX. Gustav Herdan (1897-1968)

Geb. 21.1.1897 in Brünn (Mähren; Mutter Anna, Vater Adolf, Kaufmann); gest. 16.11.1968 (Bournemouth). Jurist, Statistiker und Linguist.

Besuch der ersten deutschen Staatsrealschule in Brünn, Reifezeugnis 1915, Maturitätszeugnis Staatsgymnasium Brünn 1916, Studium der Rechtswissenschaft ab WS 1917/18 in Wien und Prag (deutsche Universität), dazwischen 2 Jahre Militärdienst; Promotion 1923 an der deutschen Universität Prag; zu dieser Zeit wurden von Jura-Promovenden keine Dissertationen verfasst. Danach Tätigkeit am Landesgericht Brünn; ab 1933 Studium vor allem des Chinesischen in Berlin, London (Diplom für klassisches Chinesisch), Prag und Wien, 1937 in Wien abgeschlossen mit Promotion in Sinologie (ostasiatische Sprachen) und englischer Philologie. 1938 Emigration nach England; Studium der Mathematik und Statistik; stellt 1939-1945 seine Kenntnisse der Statistik in den Dienst der englischen Kriegswirtschaft. Arbeit als Statistiker in der Industrie. Ab 1948 „Lecturer in Statistics“ in der Faculty of Medicine der Universität Bristol.

Mitglied der American Statistical Society, Fellow der Royal Statistical Society, Mitglied der Linguistic Society of America.

Herdans große Bedeutung für die Sprachwissenschaft besteht darin, dass er wohl als erster eine Gesamtdarstellung der Quantitativen Linguistik vorgelegt hat. Ein wesentlicher Aspekt seiner Arbeit ist die Entwicklung und Überprüfung von mathematisch formulierten Sprachgesetzen („statistical laws“). Seine Auffassung hierzu kommt u.a. im folgenden Zitat zum Ausdruck: „The masses of linguistic forms...are a part of the physical universe, and as such are subject to the laws which govern mass assemblies of any kind... This is how the need for statistical linguistics arises“ (Herdan 1960a: 3).

In Anknüpfung an Saussures Dichotomie von *langue* und *parole* sowie an die Informationstheorie und Kybernetik steht er zusammen mit Pierre Guiraud und Charles Muller für den Aufschwung der Quantitativen Linguistik in den 1950er/ 1960er Jahren (Aichele 2005: 18). Dabei behandelt er eine große Vielfalt von Themen: Fragen der Identifikation anonymer Autoren, Stilometrie, Sprachwandel und -mischung, Anwendung der Informationstheorie, Type-token-Relation, Wortlängen- und Wortfrequenzverteilungen, Zusammenhang zwischen Textlänge und Vokabularumfang sowie zwischen Stilistik und Sprachtypologie. Ein weiteres Thema ist ihm das Deutsch der Nationalsozialisten (Herdan 1960a: 263ff.). In seinen Werken werden etliche Sprachgesetze vorgestellt, darunter die Zipf- bzw. Zipf-Mandelbrot-Verteilung, Poisson-Verteilung, Lognormalverteilung. Auch wenn nicht jedes Detail heute genau so gesehen wird wie von ihm, ist Herdan doch einer der Pioniere der Quantitativen Linguistik. Zu vielen dieser Theman hat er mit der Unterstützung seiner Studenten eine Fülle von Daten erarbeitet, die man auch aus dem Blickwinkel neuer theoretischer Überlegungen nutzen kann (vgl. z.B. Best & Zhu 2001: 103ff.).

Herdan studierte eher Philologie als Linguistik und haftete – wie zu seiner Zeit alle Linguisten – an den Lehren von F. de Saussure und denen des Prager Strukturalismus. Dieser

Hintergrund öffnete ihm einige Tore, auf der anderen Seite hinderte er ihn, einen Schritt wieter zu gehen. 40 Jahre nach seinem Tod und in Anbetracht der Entwicklung in der Quantitativen Linguistik ist es nicht schwer, die Irrtümer zu sehen, denen er unterlag. Seine Kritiker, die ihn eher vom linguistischen Standpunkt aus rezensiert haben, kritisierten mehr seinen „nichtlinguistischen" Blick auf Sprachphänomene und ihre Interpretationen, seltener seine Methoden. Nichtsdestoweniger brachte er eine ganze Reihe von Problemen zum Vorschein, deren konsequente Weiterführung neue Bereiche der Linguistik eröffnen könnte.

Herdan nahm den Kampf mit „qualitativen" Linguisten betont engagiert auf und griff besonders die Vertreter der damals sich neu entwickelnden generativen Grammatik bei jeder Gelegenheit an. Diplomatie war nicht gerade seine starke Seite. In damaliger Zeit konnte er die Auseinandersetzung nicht für sich entscheiden; heute hat sich die Situation jedoch beträchtlich geändert. Es ist zu bedauern, dass er auch gegen Vertreter der Quantitativen Linguistik eine negative Einstellung hatte. Zipf und sein Prinzip der geringsten Anstrengung sowie sein Gesetz, das heutzutage in mindestens 20 wissenschaftlichen Disziplinen seinen Platz gefunden hat, lehnte er schroff ab. Heute sind Zipfs Entdeckungen die Grundlage der synergetischen Linguistik und sein Prinzip, das axiomatisch gilt, wurde in zahlreiche Spezialfälle aufgespaltet.

Von Herdan kann man jedoch sehr viel lernen. Es sind nicht so sehr die Methoden und Ansätze, die er benutzte, bzw. die Interpretationen, die er ihnen gab, sondern eher die Fülle der Probleme, die er in die Diskussion brachte. Sicherlich sind manche von ihnen Pseudoprobleme oder nicht gerade adäquat gelöste Ansätze, aber man kann aus ihnen ersehen, welche Richtungen möglich sind. Er wird heute noch immer oft zitiert, im positiven Sinne (vgl. u.a. Köhler, Altmann & Piotrowski 2005; Nikitopoulos 1980). Vielleicht hat er sich in seinen linguistischen Bemühungen allzusehr auf seine eigenen linguistischen Kenntnisse verlassen und jegliche Kooperation mit Linguisten vermieden, im Gegensatz zur Medizin, wo er nur als Statistiker wirkte und mit anderen kooperierte.

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Hinweis: Herdan hat allein oder mit anderen zusammen eine ganze Reihe weiterer Untersuchungen veröffentlicht, vor allem zu medizinischen Themen.

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XXXI. B.I. Jarcho as a pioneer of the exact study of literature

The Russian philologist Boris Isaakovič Jarcho (Engl. transliteration also: Yarkho) (1889-1942) holds a prominent position in the history of quantitative approaches. He was born in Moscow, on March 14th (26th), where he studied at the historical-philological faculty, graduating in 1912. After his graduation he spent some time in Heidelberg and Berlin to broaden his knowledge in the field of classical philology. Returning to Moscow in 1916, he worked as an assistant professor at Lomonosov Moscow State University and became a member of the well-known Moscow Linguistic Circle MLK (Moskovskij lingvističeskij kružok) in 1921.

In 1921 he was accepted as a full member of the Russian Academy of the Science of Arts ("Rossijskaja Akademija Chudožestvennych Nauk" – RACHN, later, in 1925, renamed in "Gosudarstvennaja Akademija Chudožestvennych Nauk" – GACHN). In the academy, he headed "The Cabinet for Theoretical Poetics" and "The Commission for Literary Translation". After the liquidation of the GACHN in 1930, Jarcho was mainly engaged with the translations of literary texts. In the context of the affair of the „nemcy-slovarniki" he was arrested in 1935 and sentenced to three years of prison, which was later changed to a banishment to Omsk.

B.I. Jarcho (1889-1942)

I He died in 1942 – completely isolated from the academic life – in the town of Sarapul (cf. 1969, Šapir 1990, Akimova/ Šapir 2006).

In addition to his main scientific foci in medieval literature, stylistics, metrics, poetics and theory of the drama, his theoretical and methodological contribution to the exact analysis of literary text should be emphasized. His concept of an exact analysis of literary texts can be integrated into the Russian history of quantitative approaches in the study of literature and linguistics (cf. Grzybek/Kelih 2005, Kelih 2007). Furthermore, Jarcho's contribution is to be understood as a scientific link between the linguistic-orientated Moscow Linguistic Circle (a main institution of the Russian Formalism) and the phenomenologically orientated formal-philosophical school (located at the above-mentioned GACHN), headed by Gustav G. Špet, an important Russian follower of Edmund Husserl.

Along with A. Belyj, B.V. Tomaševskij and G.A. Šengeli, B.I. Jarcho made one of the most comprehensive and important contributions to the application of quantitative methods in the analysis of literary texts. It should also be noted that his contribution has been adequately appreciated only in the last years, after the publication of his main monograph "Methodology of a Precise Science of Literature [Metodologija točnogo literaturovedenija]" in 2006 by Russian philologists M.V. Akimova and M.L. Šapir (cf. Jarcho 2006). It is impossible to discuss all his ideas and considerations in the field of qualitative and quantitative text analysis (cf. Margolin 1979, Šapir 2005, Kelih 2007a: 122f) in this article; therefore, we will focus our attention on his main contributions in statistical and empirical text analysis, based on his works (Jarcho 1925, 1927, 1935, 1969, 1984, 2006).

Jarcho defined the study of literature as a nomothetic science with linguistics and statistics as their main auxiliary disciplines. For him, the main precondition for an empirical and statistic-based analysis of literary texts is the definition of the used literary terms. Following Jarcho (1984: 198) "there is no statistical analysis without a 'morphological' [in the sense of linguistic] analysis." The second auxiliary discipline, statistics, has the function to support the exact and „objective" analysis of the underlying morphological categories. In this respect – according to Jarcho – it is possible and reasonable to build up the study of literature in analogy to natural sciences as an exact science. His concept should not be understood as a visionary project, but rather as a partly realized project by Jarcho and his colleagues (N.V. Lapšina, I.K. Romanovič).

The frequency of formal text characteristics is considered to be the central component of his exact text analysis. This approach has been justified by his understanding of the "literaricity"[literaturnost'] of a text. He defined the "literaricity" as the totality of text elements, which have the potential capacity to "inspire" the readers' aesthetic perception. An aesthetic perception – according to Jarcho – is mainly supported by the frequency of text elements, if a certain frequency occurs in a specific proportion. He assumes that the aesthetic effect of unusualness is triggered by a specific occurrence of elements, which a reader perceives as unusual.

In addition to this quantitatively based „reception aesthetics" Jarcho developed an analysis of literary text on manifold structural levels. This analysis contains a statistical "phonic" analysis of metrical forms ("slovesnaja instrumentovka", cesura, pause, strophe and rhythm), stylistics (occurrence of figures of speech, alliterations, metaphors, metonymies), a quantitative text typology, including a quantitative style-comparison of literary texts as well as poetics (frequency of motifs and sujets, quantification of the "nearness" of the content of

literary works). Moreover, his aim was to point out interrelations between the above-mentioned formal text characteristics.

Jarcho's exceedingly comprehensive statistical analysis of the formal text structure has been designed to be applied not only to a synchronic, but also to a diachronic level. The diachronic approach includes a quantitative analysis of the historical changes within literature (cf. Jarcho 1984a: 22). The primary function of the analysis of text characteristics aims at an exact description of changes in literary text types and schools.

At first glance, the framework for an exact text analysis presented above could be understood as an atomistic and positivistic collection of facts. However, it should be stressed that an analysis of frequencies and occurrences of text characteristics is only the first step. The second, and more important step, is the discovery of statistical laws and regularities, e.g. the interactions and interrelations between formal elements in literary works. But these interrelations and interactions are only of interest, if they occur frequently.

At this point, the nomothetic character of Jarcho's exact text analysis is obvious. In other words, it includes the inductive discovery of textual interrelations and laws, which are not interpreted in a deterministic way, but rather in a statistical and empirical way: The postulated laws and regularities must be validated by further research, and for Jarcho, the validity of a law depends on the number of observed empirical exceptions.

The above-mentioned ideas and concepts are the basis for an exact text analysis. It must be emphasized that Jarcho and his colleagues from GACHN made quite a number of empirical-statistical analyses on several aspects of the structure of literary texts. Their studies include analyses of the frequency of metrical forms in poems (cf. Timofeev 1928a, 1928b, Lapšina/Romanovič/Jarcho 1934, Lapšina/Romanovič/Jarcho 1966), the rhythm in verses and prose (cf. Jarcho 1928a, 1928b), as well as the quantitative analysis of the historical changes of literature, in which Jarcho (1997) tried to distinguish classicism from romanticism, based on the frequency of entries in French tragedies. Moreover, his attempt to measure the "distance of ideas" between French comedies and tragedies (cf. Jarcho 1999/2000) should be mentioned.

In addition to these numerous empirical studies, Jarcho's exact analysis of literary texts have a high statistical and methodological standard. It is more or less reliable that Jarcho is the first, who – relating to the history of quantitative approaches in Russian linguistics and study of literature – discussed and used the analysis of correlation (cf. Jarcho 1935: 59ff.; Jarcho 2006: 225ff.). In the context of correlation analysis his principle of compensation must be particularly highlighted. For Jarcho, the principle of compensation is a balancing mechanism, which is based on the frequency of formal features in poetical and folkloristic texts: The increase of the frequency of a certain text characteristic (1) implies the decrease of the frequency of another text feature (2).

In Jarcho (1935), he demonstrated the principle of compensation on German, Russian and Spanish častuška: The high frequency of rhetorical devices (anaphora, epanaphora, epiphora, etc.) results in a lower occurrence of rhythmical structures. A similar interrelation has been observed between the frequency of rhyme and the „strength" of the syntactical conjunction[1] of the analyzed častuškas. Seen from this perspective, Jarcho pointed out an important interrelation in the structure of text, related to the frequency of textual characteristics. This basic principle (compensation) is of utmost relevance still today (for more details see Kelih 2007b).

A further important contribution to the field of statistical text analysis is his extended discussion on the relevance of frequency distributions for linguistics and literary studies (cf.

[1] Jarcho (1935: 54) does not define his concept of the syntactic "strengths". He only illustrates it by some examples. So it can be concluded that the discussed "strengths" is a more or less subjective classification of the syntactic structure of the častuška.

Jarcho 2006: 158ff). Jarcho realized the importance of calculating descriptive parameters like the mean and the standard deviation, which, for Jarcho, give a more detailed insight into the frequency distribution of textual data. Moreover, he discusses the normal distribution (referred to by Jarcho as „krivaja-Ketle/Quetelet-curve") and some other distributions of Pearson's type. Jarcho considered the normal distribution to be irrelevant for the study of literary texts (e.g. the frequency of accents in verse texts), and he assumed that rather asymmetrical distributions come into play. However, Jarcho neither postulated appropriate distributions, nor discussed he statistical methods, which yield information about the significance or non-significance of the normal distribution. Nevertheless, according to Jarcho, it should be taken into account that normally distributed data potentially do not reflect data from literary texts but rather from „ordinary" language. Whether this claim can be confirmed from today's point of view – linguistic and literary text data are mainly not normally distributed (cf. Köhler 2005) – Jarcho's assumption can be understood as a first qualitative interpretation of the specific shape of language and speech distributions.

Coming to an end with our survey of Jarcho's contributions, the question of modeling the history of literature should be mentioned. It can be claimed that Jarcho may be recognized as a pioneer in this field. He assumed the history of literature to be a process which can be mathematically described. In his study of the frequency of acts in French tragedies (cf. Jarcho 1999/2000) he showed that the changes in the frequency of speaking characters in relation to the actors on the scene are not only a specific characteristic of a literary era, but also obey a mathematically describable development. The mentioned relation between speaking characters and actors on the scene has the form of an S-shaped development, which Jarcho termed „zakon regressii/regression law".

Even if Jarcho did not investigate this question with specific statistical methods, e.g. nonlinear regression models, his "regression law" is a first empirical attempt to find some statistical laws in the development of the history of literature. According to Jarcho (1997: 257) the S-shaped curve can also be obtained in physical, chemical and economical processes. It would be of interest for further research to integrate Jarcho's "regression law" into the well known "Piotrovskij Law".

Taking into account B.I. Jarcho's numerous theoretical, methodological and empirical contributions to the application of statistical methods in text analysis, it is justified to regard him not only as a pioneer of Russian quantitative text analysis, but also as a central proponent of quantitative linguistics and study of literature.

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Emmerich Kelih, Graz