Computational Stylometry of Wittgenstein's "Diktat für Schlick".

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Abstract

Using techniques from computational stylometry we will examine some of the dictated writings of Ludwig Wittgenstein which have been made available by the Wittgenstein Archives at the University of Bergen. Our purpose is to give an example of how computational stylometry can be used to help answer concrete questions of Wittgenstein research, and thus to explore how computational stylometry can be applied to issues of philosophical authorship more generally. In particular we use computational stylometry to help examine the question of whether the so-called "Diktat für Schlick" was in fact dictated by Wittgenstein, and if yes, whether to Schlick or Waismann. To this end we compare documents known to be written by Wittgenstein in person; the "Diktat für Schlick"; and samples of some of Schlick's and Waismann's (the potential amanuenses) own writings. Using the "Stylometry with R" package of Eder and Rybicki, the degree of similarity and dissimilarity between documents is calculated by Burrows' delta measure, and the results are displayed using Cluster Analysis, Multidimensional Scaling and Bootstrap Consensus Trees. The documents are each characterised by the frequencies of the 300 most frequent words in the entire corpus, normalised by document length. Our main findings are that the "Diktat für Schlick" is far more similar to Wittgenstein's writings than those of either Schlick or Waismann, and that the writings of Wittgenstein and Schlick or Waismann are stylometrically quite distinct.

Keywords: computational stylometry; Wittgenstein

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1. Computational Stylometry of Wittgenstein's "Diktat für Schlick"

Using techniques from computational stylometry (CS) we will examine some of the dictated writings of Ludwig Wittgenstein which have been made available by the Wittgenstein Archives at the University of Bergen. Our purpose is to give an example of how computational stylometry can be used to help answer concrete questions of Wittgenstein research, and thus to explore how computational stylometry can be applied to issues of philosophical authorship more generally. Our concrete questions of Wittgenstein research concern the so-called "Diktat für Schlick" which in the Wittgenstein Nachlass catalogue is labelled item 302 (von Wright 1982). It is debated when this item was composed, as is also the authorship: Georg Henrik von Wright, one of the original Wittgenstein Nachlass trustees and author of the so-called von Wright catalogue of the Nachlass, attributed this dictation to Wittgenstein, whether dictated to Friedrich Waismann for Moritz Schlick or directly to Schlick. Both Waismann and Schlick were associated with the Vienna Circle and were close philosophical companions of Wittgenstein in the late 20s and early 30s. The view that the "Diktat für Schlick" was authored by Wittgenstein was recently questioned (see Schulte 2011 and Manninnen 2011); in this paper we are, however, not primarily concerned with the research literature on the "Diktat für Schlick" as such. Rather, our principal interest is to investigate how computational stylometry can be meaningfully applied to issues discussed in this literature, and in particular to the issues of authorship and dating of the "Diktat für Schlick". Thus, we are primarily interested in an exercise in procedure and method: what can CS, using *this specific method* on *these specific texts*, tell us in relation to our *specific research questions?* Nevertheless, we hope that our results can also be of direct use for those who indeed want to settle these issues and find out which of the competing views is true.

Our first concrete research question is (2a): *In terms of authorship, what can CS tell us about where to place the "Diktat für Schlick"?* Close to Wittgenstein, close to Schlick or close to Waismann? "Authorship" is here understood in a wide sense and includes: author of autograph, author of dictation, author of text which has been the basis for dictation by others, or also author of text which has been the basis for note-taking by others. Thus, we want inter alia to find out what evidence CS can add with regard to the question whether the "Diktat für Schlick" was indeed dictated by Wittgenstein, and if not, by whom or to whom. If it was not dictated by Wittgenstein, can we still identify the style of the dictation to bear the marks of a Wittgensteinian text? And if it was dictated by Wittgenstein, could it still be that the dictation reflects the writing style of the amanuensis as opposed to the writing style of Wittgenstein? This leads to our question (2b): *If the item was dictated by Wittgenstein, can one with the help of CS determine whether it reflects the writing style of the amanuensis, and which amanuensis, as opposed to the style of Wittgenstein himself?* This can be of relevance for dealing with the question, whether the "Diktat für Schlick", if dictated by Wittgenstein, was dictated to Schlick or Waismann.

If the results from our CS analyses suggest that the style of the dictation is close to the style of other Wittgenstein texts, then this will still be compatible with both views, the one which holds that Wittgenstein was the one who dictated the item, and the other one, that it was someone else who authored the dictation, albeit in a truly Wittgensteinian style. Indeed, our analyses show that the style of the "Diktat für Schlick" is closer to the style of Wittgenstein than to the styles of Schlick or Waismann respectively; if we take this to imply that the text is by Wittgenstein, then we can use other Wittgenstein texts to confine the debated date of the "Diktat" further. Does the "Diktat für Schlick" stem from 1932-33 or rather from 1933-34? This is our question (2c): *In terms of chronology, what does CS tell us about where to place the "Diktat für Schlick"?* For answering this question, we compare the style of the "Diktat" with the style of two versions of Wittgenstein's so-called Big Typescript. This leads us straight to the issue of the text basis for our analyses: which texts is our CS work based upon?

a) DS ("Diktat für Schlick" alias item 302): This item exists in four versions.[1] Our CS work is based upon the typescript version *D302/I* which is published in the *Bergen Electronic Edition* of Wittgenstein's Nachlass (2000) and contains 32 pages.

b) BT (Big Typescript alias item 213), a typescript of 768 pages, dictated by Wittgenstein to a typist 1932-33 and later, 1933-34, in parts heavily revised in Wittgenstein's hand. BTt refers to the typescript version without handwritten annotations and thus includes just the typed text: this is of undisputed authorship. BTh refers to the typescript including the handwritten annotations, also this is of undisputed authorship. Both are available from *WittgensteinSource* (Wittgenstein 2009) and the Wittgenstein Archives (WAB) Website.[2] The single chapters of the Big Typescript are referred to by "BT" and the first words of the chapter titles. Our CS work on research questions (2a) and (2b) is based upon WAB's normalized version of BTh, thus the typescript including the handwritten revisions; our CS work on research question (2c) includes also BTt. The additional research question (2d) has been formulated with regard to the relation between BTh and BTt: *Is there according to CS a discernible difference in style between BTh and BTt?*

c) SCH, including the following texts (in German) by Schlick from the "Wiener Zeit", amounting together to about 165 pages):[3]

   a. Erkenntnistheorie und moderne Physik
   b. Erleben, Erkennen, Metaphysik
   c. Ernst Mach, der Philosoph
   d. Gibt es ein Materiales Apriori?
   e. Positivismus und Realismus
   f. Quantentheorie und Erkennbarkeit der Natur
   g. Über das Fundament der Erkenntnis
   h. Vom Sinn des Lebens
   i. Die Wende der Philosophie
   j. Wilhelm Jerusalem zum Gedächtnis

d) WAI, including the following texts (in German) by Waismann, also from the Vienna period, and amounting together to about 20 pages:
   a. Logische Analyse des Wahrscheinlichkeitsbegriffs (1930)
   b. Die Natur des Reduzibilitätsaxioms (1928)

2. Summary of Results

To answer our research questions, we did CS comparisons on documents known to be written by Wittgenstein in person (the Big Typescript BT - both as BTt: the Big Typescript without handwritten annotations, thus the earlier version of the text, and as BTh: the Big Typescript incl. handwritten annotations, thus the later version of the text), the "Diktat für Schlick" (DS), and the

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[1] Iven 2009:71: "Nach dem heutigen Erkenntnisstand liegen uns vier Fassungen des *Diktats für Schlick* vor:
D302/I Typoskript im Wittgenstein-Nachlass
D302/II Typoskript im Waismann-Nachlass
D302/III Stenogramm im Schlick-Nachlass
D302/IV Typoskript im Schlick-Nachlass"

[2] http://wab.uib.no/wab_hw.page/.

[3] Mathias Iven and the Moritz Schlick Gesamtausgabe project (http://www.moritz-schlick.de/) have been so kind to provide us with this text basis.

above samples of some of Schlick's and Waismann's (the most plausible potential amanuenses) own writings, SCH and WAI. We achieved the following results:

- 4a. Comparison DS – BTh – SCH. Results: DS is closer to BTh than to SCH. CS thus suggests that DS is closer to Wittgenstein authorship than to Schlick authorship.

- 4b. Comparison DS – BTh – SCH – WAI. Results: DS is closer to BTh than to either WAI or SCH. CS thus suggests that DS is closer to Wittgenstein authorship than to Waismann authorship, and that WAI and SCH are stylometrically not distinct.

- 4c. Comparison DS – BTt – BTh. Results: DS is closer to BTh than to BTt. CS thus suggests that DS is to be dated 1933-34 rather than 1932-33.

Finally, we also wanted to establish the amount of stylistic difference between the Big Typescript without handwritten annotations (BTt) and the version including the revisions in hand (BTh):

- 4d. Comparison BTt – BTh. Results: CS establishes most difference for the five chapters of the Big Typescript which have been most heavily revised.

In the following, we describe our research tasks and results in detail.

3. Methodology

3.1 Computer Stylometry

Computer stylometry is the computational analysis of writing style. Typically the techniques of computer stylometry are used to resolve cases of disputed authorship, but in this paper we will also look at the related problems of the relation between dictated and manuscript texts, and the chronology of authorship. Many successful studies have used the Most Frequent Words (MFW) in the entire corpus as indicators of writing style, since rarely-occurring words are too infrequent for statistical analysis, and medium-frequency words tell us more about the topic of the texts than the style they are written in. Burrows (2002) recommends using the 50-100 MFWs, but other authors use much longer lists.

Although many readers of Henry James feel that his alternation between handwriting and dictation does result in a discernible change of literary style, Hoover (2009) was unable to demonstrate this stylometrically. He used a technique called hierarchical agglomerative clustering, which will be described in this paper, to show that effect of dictation on writing style was not great in Thomas Hardy's "A Laodicean". Due to a bladder inflammation, Hardy had been ordered by his doctor to lie with his feet higher than his head, and thus could only write by means of dictation to his wife. In the same study, Conrad's novella "The End of the Tether", which was dictated to Ford Madox Ford because of time pressure resulting from some original drafts being accidentally burnt, again revealed no evidence that dictation altered Conrad's style. Walter Scott suffered stomach pains, probably because of gall-bladder disease, and thus had to dictate about half of Ivanhoe, but this again could not be demonstrated by Hoover's stylometric techniques. It may have been that the differences between handwritten and dictated texts had been blurred by later revision of some of these texts, since James and Conrad tended to revise their work extensively, but Scott and Conrad are known to have revised their texts very little. Similarly, Rybicki (2012) writes about "translator invisibility" – Burrows' delta measure (another stylometric technique to be described in this paper) fails to identify the translator, but discrimination of translated texts is possible according to the identity of the original author. The question of dictation also occurs in New Testament stylometry: Tertius is named as the scribe for one of Paul's letters (Romans 16:22), while Paul declares that he is writing in his own hand in five others (Colossians 4:18, Galatians 6:11, 1 Corinthians 16:21, Thessalonians 3:17, Philemon 1:19) (http://bible.cc/romans/16-22.htm).

3.2 Burrows' Delta

The stylometric techniques used in this paper were performed using Eder and Rybicki's (2010) "Stylistics in R" package, which is freely downloadable. The package first determines the list of MFWs in the corpus as a whole, and records their "normalised" frequencies, i.e. the frequencies of these words expressed as a percentage of the words in the corpus as a whole. These normalised frequencies are stored in a file called "freq.table.both.sets". In the example shown in Table 1, the normalised frequencies are shown for the 6 most frequent words in a corpus of 4 German texts, above the mean and standard deviation for each normalised word frequency. The mean (a type of "average") and the standard deviation (a measure of spread in the data, which is greater if the data values differ more widely from each other) may for example be found for "die" using the R commands:

```
>die = c(2.675, 3.284, 2.852, 2.608)
>mean(die)
>sd(die)
```

Table 1

Normalised frequencies of the 6 MFW in 4 German Texts

	Die	**Der**	**Das**	**Ist**	**Und**	**Nicht**
BTh Allgemeinheit	2.675	2.551	1.673	1.993	2.107	1.942
BTh Bedeutung	3.284	2.996	2.718	2.123	1.706	1.498
BTh Erwartung	2.852	2.721	2.545	2.583	1.591	1.968
SCH Positivismus	2.608	3.048	1.045	1.607	1.941	1.309
Mean	2.855	2.829	1.995	2.077	1.836	1.679
Standard deviation	0.304	0.234	0.781	0.403	0.232	0.328

The values in Table 1 are converted into "z-scores", which reflect the extent to which the normalised word frequencies within a particular text are above or below average for the set of texts as a whole. The formula for the z-score is:

$$z = \frac{(NF - mean)}{SD}$$

where NF is the normalised frequency and SD is the standard deviation. For example, the normalised frequency of "die" in "BTh Allgemeinheit" is 2.675, and the mean NF of "die" over all 4 texts is "2.855" with an SD of 0.304. Thus the z-score for "die" in "BTh Allgemeinheit" is (2.675 – 2.855) / 0.304 = - 0.592, showing that "die" is slightly less frequent in "BTh Allgemeinheit" than it is within the set of all 4 texts.

Table 2

z-scores for the 6 MFW in 4 German Texts

	Die	**Der**	**Das**	**Ist**	**Und**	**Nicht**
BTh Allgemeinheit	-0.592	-1.187	-0.412	-0.207	1.167	0.801
BTh Bedeutung	1.412	0.713	0.925	0.115	-0.561	-0.552
BTh Erwartung	-0.009	-0.459	0.703	1.259	-1.058	0.881
SCH Positivismus	-0.810	0.933	-1.216	-1.166	0.452	-1.130

All the z-scores may be found in the file "zscores.table.both.sets", as shown in Table 2. Using the "Burrows Technique" (Burrows, 2002), the table of z-scores is converted into a table of "distances" between documents, in which high values show that a document pair are dissimilar to each other, and low values show that a pair of documents are highly similar. The classic delta formula, used throughout this paper, is given below:

$$\delta(A,B) = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{f_i(A) - f_i(B)}{\sigma_i}\right|$$

An example of the use of this formula, to find the distance (called "Burrows' delta") between the documents "BTh Allgemeinheit" and "BTh Bedeutung", is given in Table 3. Each of the 6 most common words, listed in the first column, is considered in turn. In the second and third columns are the z-scores for each of these 6 words in "BTh Allgemeinheit" and "BTh Bedeutung" respectively. In the fourth column, the differences between the values in the second and third columns are recorded. In the final column are the corresponding "absolute" differences, where all negative values in the fourth column are changed to positive. The sum of the absolute differences for each word is 8.644, and this is divided by the number of words used to derive this total, giving a delta value for the dissimilarity between the two documents of 8.644 / 6 = 1.441.

Table 3

Example Calculation of Burrows' delta between "BTh Allgemeinheit" and "BTh Bedeutung"

Word	**Z(A)**	**Z(B)**	**Z(A) – Z(B)**	**| Z(A) – Z(B) |**
Die	-0.592	1.412	- 2.004	2.004
Der	-1.187	0.713	- 1.900	1.900
Das	-0.412	0.925	- 1.337	1.337
Ist	-0.207	0.115	- 0.322	0.322
Und	1.167	-0.561	1.728	1.728
Nicht	0.801	-0.552	1.353	1.353
Total				8.644
Total / N				1.441

The formula for the z-score is:The delta values for every pairwise comparison in the document set is given in the file "distance.table" , which may be viewed after running the "Stylometry with R" package, by typing "distance.table" at ">" on the next new line on the R console. The values for this example are given in Table 4. Trivially, a document has a delta score of 0 with itself, since it is identical with itself.

Table 4

Delta scores for each document pair in the corpus

	BTh Allgemeinheit	**BTh Bedeutung**	**BTh Erwartung**	**SCH Positivismus**
BTh Allgemeinheit	0	1.441	1.033	1.125
BTh Bedeutung	1.441	0	0.981	1.243
BTh Erwartung	1.033	0.981	0	1.676
SCH Positivismus	1.125	1.243	1.676	0

The values in Table 1 are converted into "z-scores", which reflect the extent to which the normalised word frequencies within a particular text are above or below average for the set of texts as a whole. The formula for the z-score is:Having derived the table of delta scores, the "Stylometry with R" package allows the results to be displayed in a number of ways, each showing the similarities and dissimilarities between the documents in its own way. The first of these is called clustering, which can be done by many different algorithms, each of which groups similar documents together and keeps dissimilar documents apart. The clustering algorithm employed by the "Stylometry with R" package is Ward's algorithm (1963), which is a form of hierarchical agglomerative clustering. This means that pairs or small sets of closely related documents are first combined into groups, then these groups are themselves combined into larger groups, until all the documents are connected into a single large cluster. This is displayed on an (on its side) tree diagram called a dendrogram, as shown in Figure 1, where the individual documents form "leaves" on the right hand side. Thus with this form of clustering, texts most similar to each other are placed on neighbouring branches.

Using the data from Table 4, we see that the closest pair of documents (with a delta value of 0.981) is "BTh Bedeutung" and "BTh Erwartung". These are joined to form a pair. Notice that the vertical line joining them points towards the value of 0.981 on the scale at the bottom. The next closest pair of documents, "SCH Positivismus" and "BTh Allgemeinheit" has a delta value of 1.125. This means that these two documents are more similar to each other than either of them is to the members of the "BTh Bedeutung"-" BTh Erwartung" pair, so "SCH Positivismus" and "BTh Allgemeinheit" are also joined to form a pair. Finally, the two pairs are joined together so that all four documents are now joined. The vertical line joining the two pairs points to a value of 1.676, which is the delta value for "SCH Positivismus" and "BTh Erwartung".

Is this cluster pattern reliable, or has it arisen as a result of the algorithm having given too much emphasis to some words in the set of MFW, and not enough emphasis to others? To check this, "Stylometry with R" enables the creation of a structure related to the dendrogram, called a "bootstrap consensus tree". A large number of "pseudoreplicate" distance matrices are generated by randomly sampling the original document-word matrix (Table 1) to create new matrices of exactly the same length and height.

A vector (set of values) is randomly generated where each value is the number of times a word column in the original document-word matrix of Table 1 will be sampled. The vector must consist of the same number of values as there were words used in the document-word matrix, and the total of these values must also be this number. If we have the same four documents and six words as in the example above, a sample selection vector of [0 1 2 0 1 2] would mean that the original column for "die" is ignored, the column for "der" is kept once, the column for "das" is used twice, and so on, to give the resampled document-word matrix shown in Table 5.

Table 5

Resampled document-word matrix

	Der	**Das**	**Das**	**Und**	**Nicht**	**Nicht**
BTh Allgemeinheit	-1.187	-0.412	-0.412	1.167	0.801	0.801
BTh Bedeutung	0.713	0.925	0.925	-0.561	-0.552	-0.552
BTh Erwartung	-0.459	0.703	0.703	-1.058	0.881	0.881
SCH Positivismus	0.933	-1.216	-1.216	0.452	-1.130	-1.130

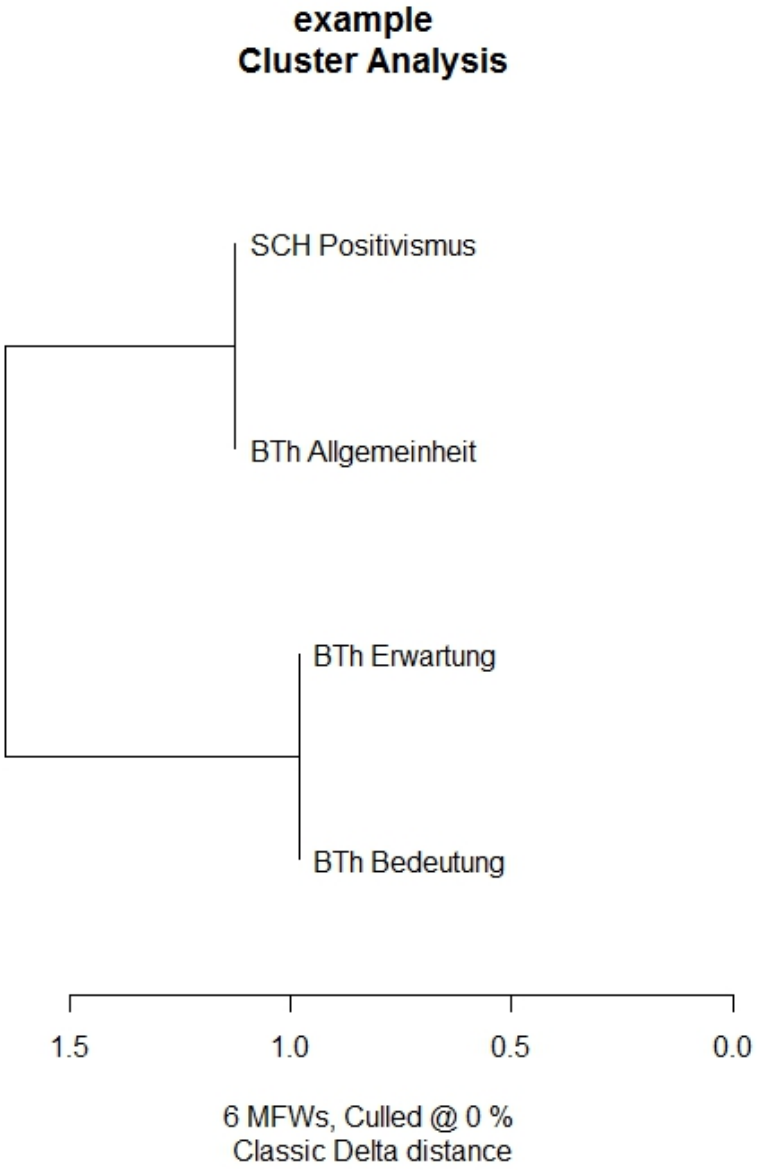

Figure 1. Cluster analysis for four German texts

For each resampled matrix a new cluster tree is formed following the same steps as for the generation of the original cluster tree. This is done hundreds or thousands of times. All the resulting clusters are analysed, and by a form of voting procedure, a final "consensus" tree is produced (Opperdoes, 1997). This analysis involves keeping a tally of how often each branch of the tree, corresponding to a pair of "nearest neighbours", is created. Boostrap consensus trees are very good because of the stability of the results - similar trees are produced every time the experiment is run. Unlike the dendrogram, bootstrap consensus trees ignore the actual scale of the distance between documents. One solution to this is to generate a few Cluster Analysis diagrams, which do maintain proportions, and find one with the individual texts arranged more or less in the same way as in the consensus tree (Rybicki, personal communication).

Multidimensional Scaling (MDS) is another visualisation technique based on the distance matrix, such as the one in Table 4. The distance matrix has as many columns as there are documents: the technique automatically identifies a number of vectors, typically 2 or 3, which is smaller than the number of documents, such that these vectors contain as much information as possible about the original distance matrix. In classical MDS, these vectors are learnt using a

procedure described by Everitt (2005:94). Representing the original distance matrix by just two vectors has the advantage of making it possible for each document to be plotted on a two-dimensional map, where the values in the vectors become the co-ordinates of the documents. Such a map is shown in Figure 2, where for example "BTh Allgemeinheit" is plotted at 0.143 on the horizontal axis and 0.693 on the vertical axis. In this representation too, more similar documents appear closer together.

Table 6

Vectors from MDS for the 4 German Texts

	Dimension 1	**Dimension 2**
BTh Allgemeinheit	0.143	0.693
BTh Bedeutung	-0.259	-0.691
BTh Erwartung	-0.763	0.168
SCH Positivismus	0.879	-0.170

To demonstrate that the reduced number of dimensions really does retain most of the information in the original distance matrix of Table 4, we can reconstruct the distance matrix fairly well from the two dimensions of our example and a measure called Euclidean Distance. If we call the dimension 1 and 2 coordinates for "BTh Allgemeinheit" a_1 and a_2 respectively, and the coordinates for "BTh Bedeutung" b_1 and b_2 respectively, then the Euclidean distance between the two documents (which we will call ED(a,b)) is

$$ED(a,b) = \sqrt{(a_1 - b_1)^2 + (a_2 - b_2)^2}$$

Which is $\sqrt{(0.143 + 0.259)^2 + (0.693 + 0.691)^2} = 1.441$

In the same way the ED values for each pairwise document comparison are found, as shown in Table 7. This matrix is very close (but not quite identical) to the distance matrix in Table 4.

Table 7
Euclidean distances between document co-ordinates

	BTh Allgemeinheit	**BTh Bedeutung**	**BTh Erwartung**	**SCH Positivismus**
BTh Allgemeinheit	0	1.441	1.047	1.135
BTh Bedeutung		0	0.996	1.251
BTh Erwartung			0	1.677
SCH Positivismus				0

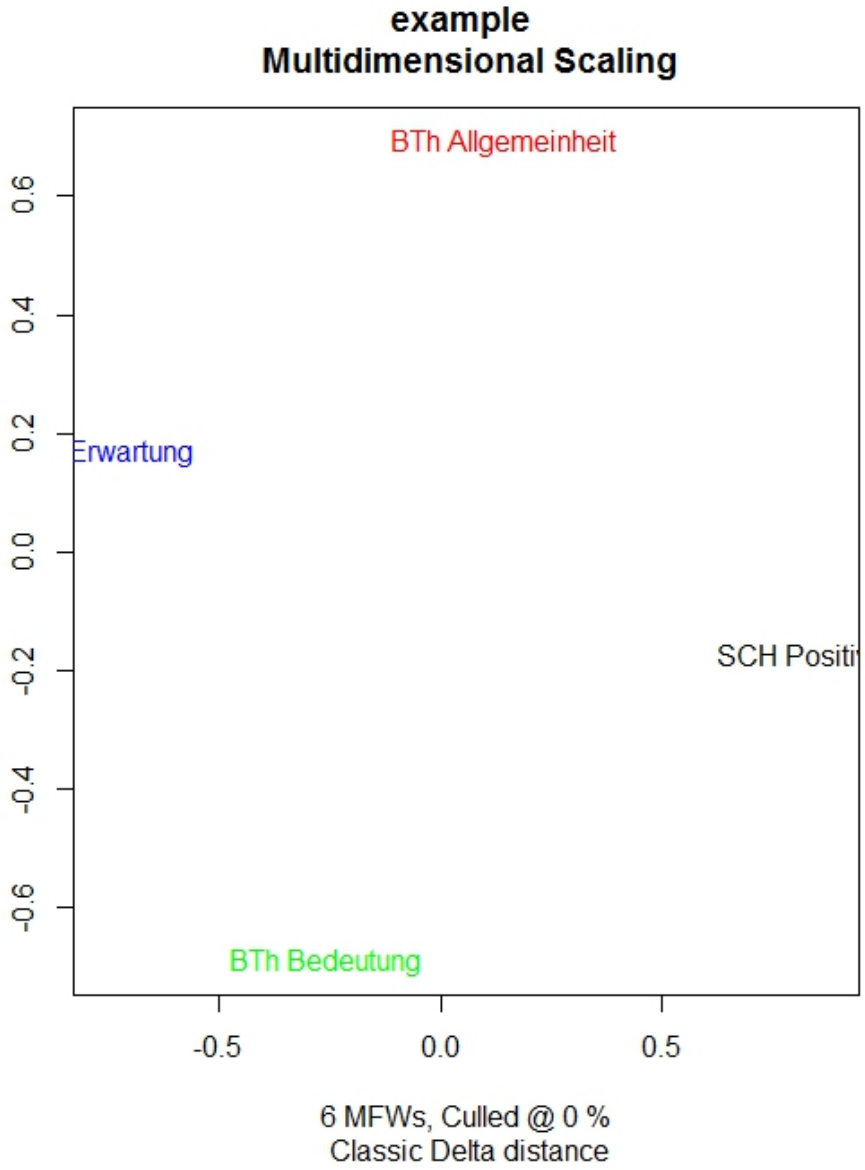

Figure 2. Two-Dimensional MDS Plot for the 4 German Texts

3.3 Technical Details: Parameter Settings

The "Stylometry with R" package can be downloaded from https://sites.google.com/site/computationalstylistics/. The site also contains the poster which serves as an instruction manual (Eder and Rybicki, 2010). In this section we will describe the various settings of the program that were used in our experiments. Readers not intending to run their own experiments using "Stylometry with R" may wish to skip the remainder of this section.

The "Classical" Burrows' delta measure is the most widely used as a measure of document dissimilarity in authorship attribution studies, although the "Stylometry with R" package does allow the selection of certain variants of delta. As well as choosing a measure for creating the document similarity matrix, it is necessary to choose a technique to display the similarities between texts – in separate runs, we chose one of "Cluster Analysis", "MDS" or "Consensus Tree". For "Cluster Analysis" and "MDS" we used the default settings (which appear ready filled-in at the start). We did not delete pronouns, although some people do this as pronouns are sometimes said to be more indicative of narrative style than individual authorship. We used minimum and maximum MFW of 300 (hence performed our analyses based on the 300

most frequent words in the corpus) and used 0% culling, where a culling rate of 100% means remove every work that doesn't appear in every text; 50% means remove the words which appear in less than half the texts. All words were reduced to lower case, and all punctuation was removed. When rerunning the package for new data, one should make sure the boxes "existing frequencies" and "existing wordlist" boxes are NOT ticked so that the program starts the process by making a new frequency table.

Table 8
Texts Used in the Analyses

Text	**Author**
Diktat für Schlick	Wittgenstein / Waismann / Schlick
WAI Wahrscheinlichkeitsbegriffs	Waismann
WAI Reduzibilitätaxioms	Waismann
BTh Allgemeinheit	Wittgenstein
BTh Bedeutung	Wittgenstein
BTh Das Augenblickliche	Wittgenstein
BTh Erwartung	Wittgenstein
BTh Gedanke	Wittgenstein
BTh Grammatik	Wittgenstein
BTh Grundlagen der Mathematik	Wittgenstein
BTh Idealismus	Wittgenstein
BTh Induktionsbeweis	Wittgenstein
BTh Intention	Wittgenstein
BTh Logischer Schluß	Wittgenstein
BTh Mathematischer Beweis	Wittgenstein
BTh Phänomenologie	Wittgenstein
BTh Philosophie	Wittgenstein
BTh Satz	Wittgenstein
BTh Über Kardinalzahlen	Wittgenstein
BTh Unendliche	Wittgenstein
BTh Verstehen	Wittgenstein
BTh Wesen der Sprache	Wittgenstein
SCH Erkenntnistheorie	Schlick
SCH Erleben	Schlick
SCH Ernst Mach	Schlick
SCH Gibt es ein	Schlick
SCH Positivismus	Schlick
SCH Über das Fundament	Schlick
SCH Vom Sinn	Schlick
SCH Wende	Schlick
SCH Wilhelm Jerusalem	Schlick

In order to run the consensus trees, it was necessary to also install a package called "ape" (analyses of phylogenetics and evolution). As this name suggests, clustering techniques are not only for grouping documents, but can also be used for examining relationships between languages and living creatures. The ape package is available in all CRAN repositories and at http://ape.mpl.ird.fr. To produce statistically-significant consensus trees, Rybicki (personal communication) suggests that one should use documents not far below 5000 words in length.

Recommended parameter settings are: minimum MFWs: 100; maximum MFWs: 1000, Increment: 100, Minimum culling 0, max culling 100, increment 20; if you tick "Consensus tree", untick all other diagram types; also untick "All Z-scores" and "All culling".

4. Analysis

Analysis 1. Comparison of Wittgenstein (BTh), Schlick (SCH) and "Diktat für Schlick"

Burrows' delta measure was determined for a pairwise comparison of all the texts listed in Table 8, with the exception of "Logische Analyse des Wahrscheinlichkeitsbegriffs" and "Die Natur des Reduzibilitätsaxioms" by Waismann. The results are displayed in the form of a Cluster Analysis, as shown in Figure 3.

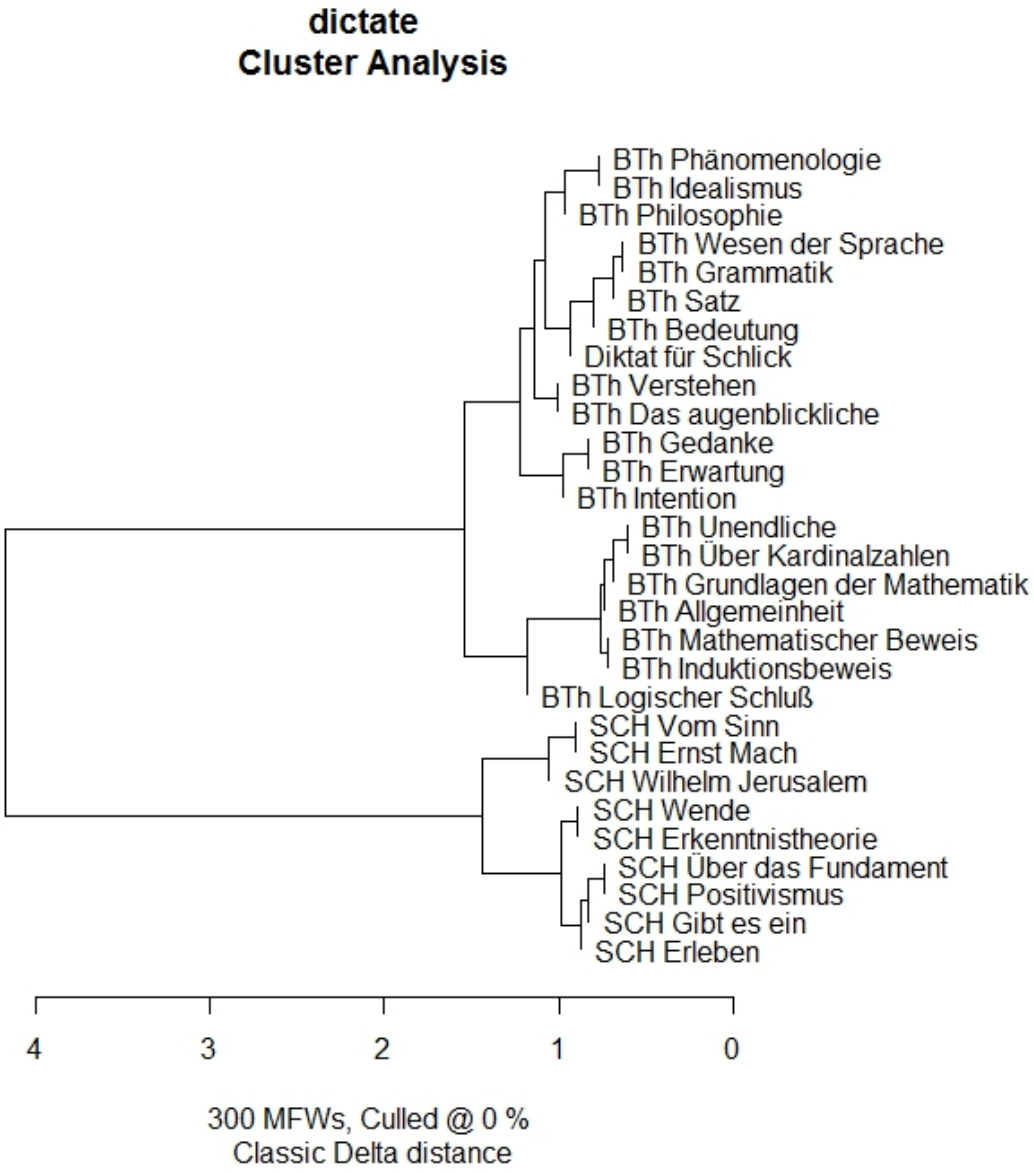

Figure 3. Cluster Analysis for a comparison of Wittgenstein, Schlick and "Diktat für Schlick"

In Figure 3, the texts by Schlick (labelled with "SCH") form a quite distinct grouping from those by Wittgenstein (labelled with "BTh"), which are grouped in the upper part of the diagram. The "Diktat für Schlick" is seen to be very similar to the Wittgenstein texts, in particular the quartet

consisting of "BTh Idealismus", "BTh Phänomenologie", "BTh Satz" and "BTh Grammatik". Thus the "Diktat für Schlick" seems much closer to Wittgenstein authorship than to Schlick authorship.

Analysis 2. Comparison of Waismann (WAI), Wittgenstein (BTh), Schlick (SCH) and "Diktat für Schlick"

In this experiment, Burrows' delta was found for a pairwise comparison of all the documents listed in Table 8. The results are displayed in each of the three ways described in Section 3. Figure 4 shows the Cluster Analysis, Figure 5 shows Multidimensional Scaling, and Figure 6 shows the Bootstrap Consensus Tree. The Cluster Analysis is similar to Figure 3, where the Waismann text was excluded, but in Figure 4 the Schlick texts now appear above the Wittgenstein texts. The Waismann text is very similar to the Schlick texts, and thus the techniques used do not discriminate between these two authors. Both Waismann and Schlick are quite distinct from Wittgenstein. Once again, "Diktat für Schlick" belongs firmly in the group of Wittgenstein writings, showing that whoever did the dictation did so very faithfully, or whoever the text was dictated to, wrote it down in the style of Wittgenstein. In Figure 5, the MDS shows all the Schlick and Waismann works positioned distinctly to the right of the Wittgenstein texts. The technique does not discriminate between Schlick and Waismann, but the values of the first dimension discriminate between Schlick/Waismann and Wittgenstein. "Diktat für Schlick" once again "belongs" to Wittgenstein. The MDS patterns are seen again in the "Bootstrap consensus diagram", of Figure 6. In each of the three diagrams for this analysis, "Diktat für Schlick" seems to belong to a quintet of stylistically-similar works: "BTh Idealismus", "BTh Phänomenologie", "Diktat für Schlick", "BTh Satz" and "BTh Grammatik".

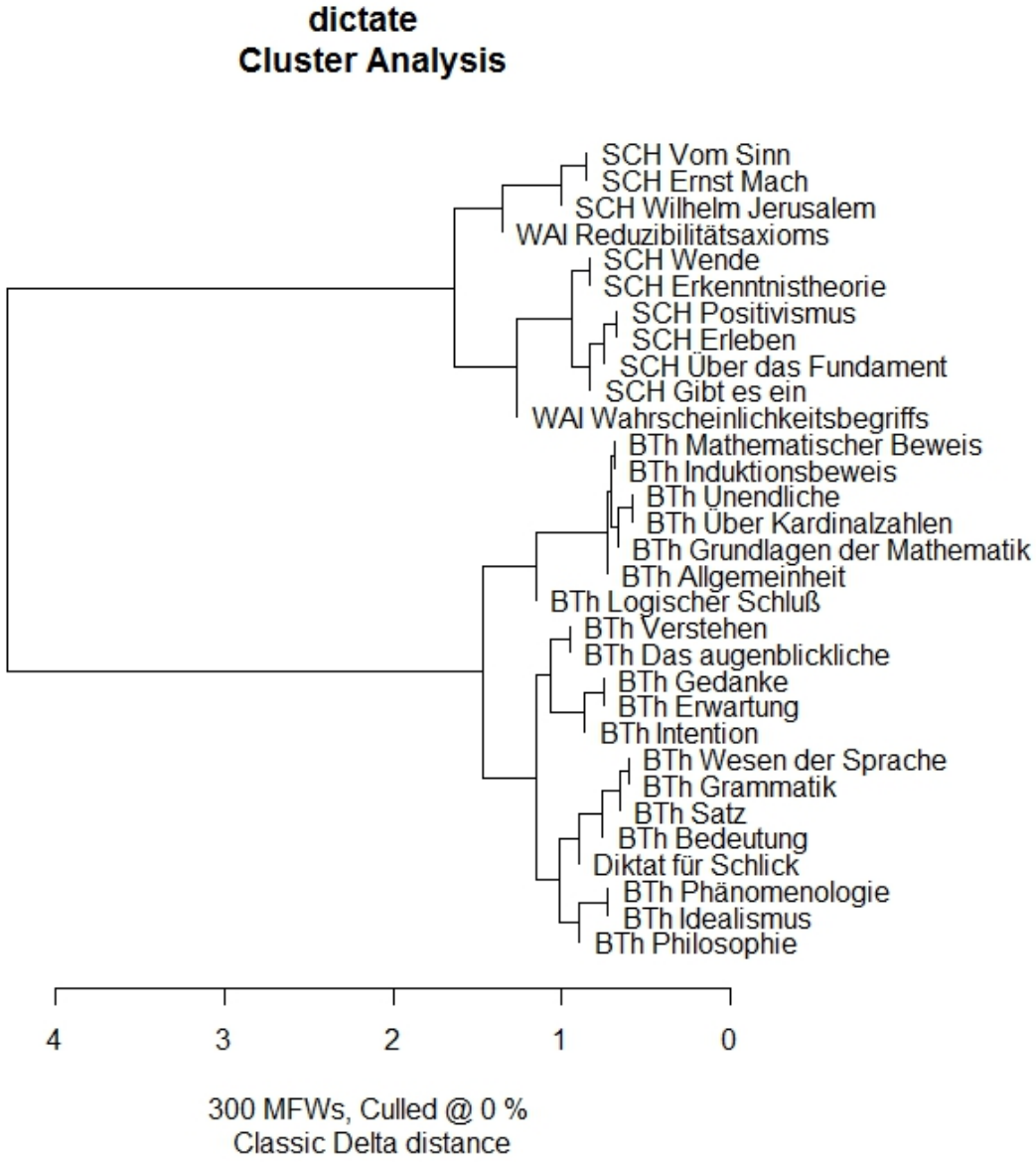

Figure 4 Cluster Analysis for the Entire Document Set

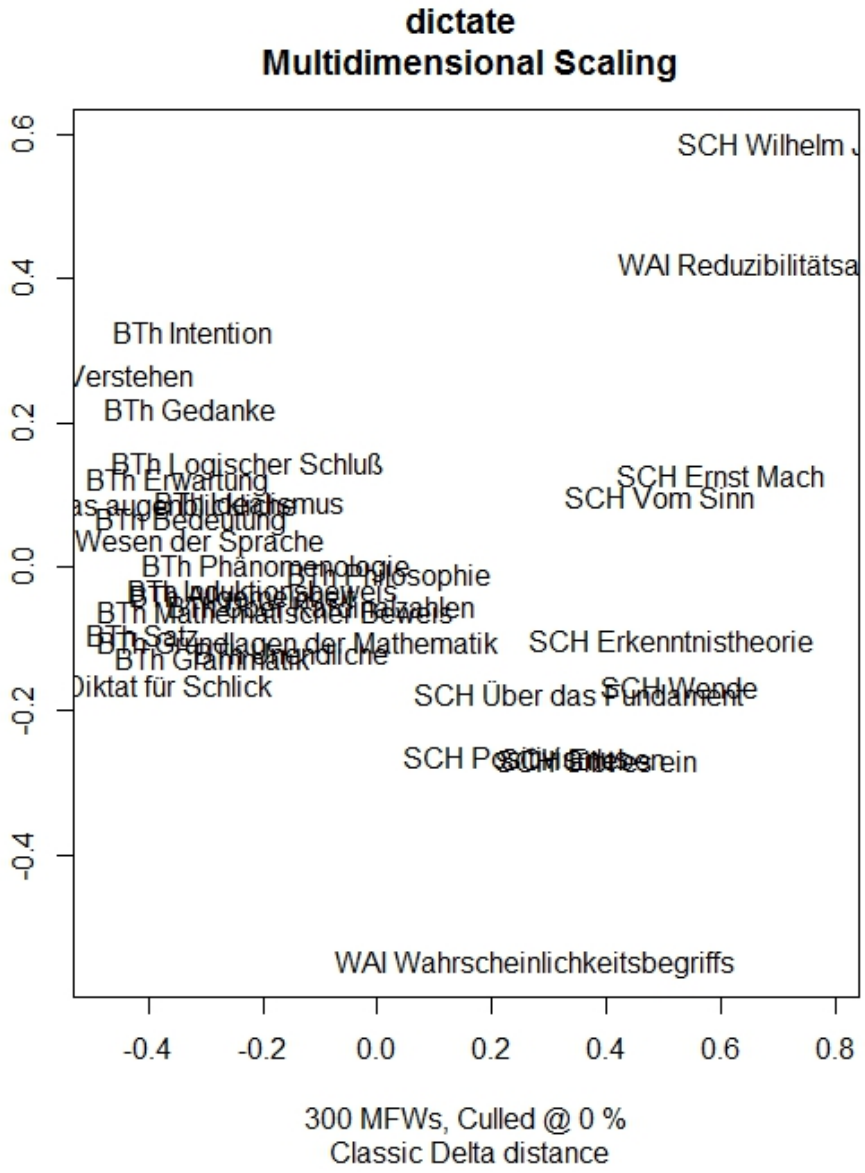

Figure 5 MDS of the Entire Document Set

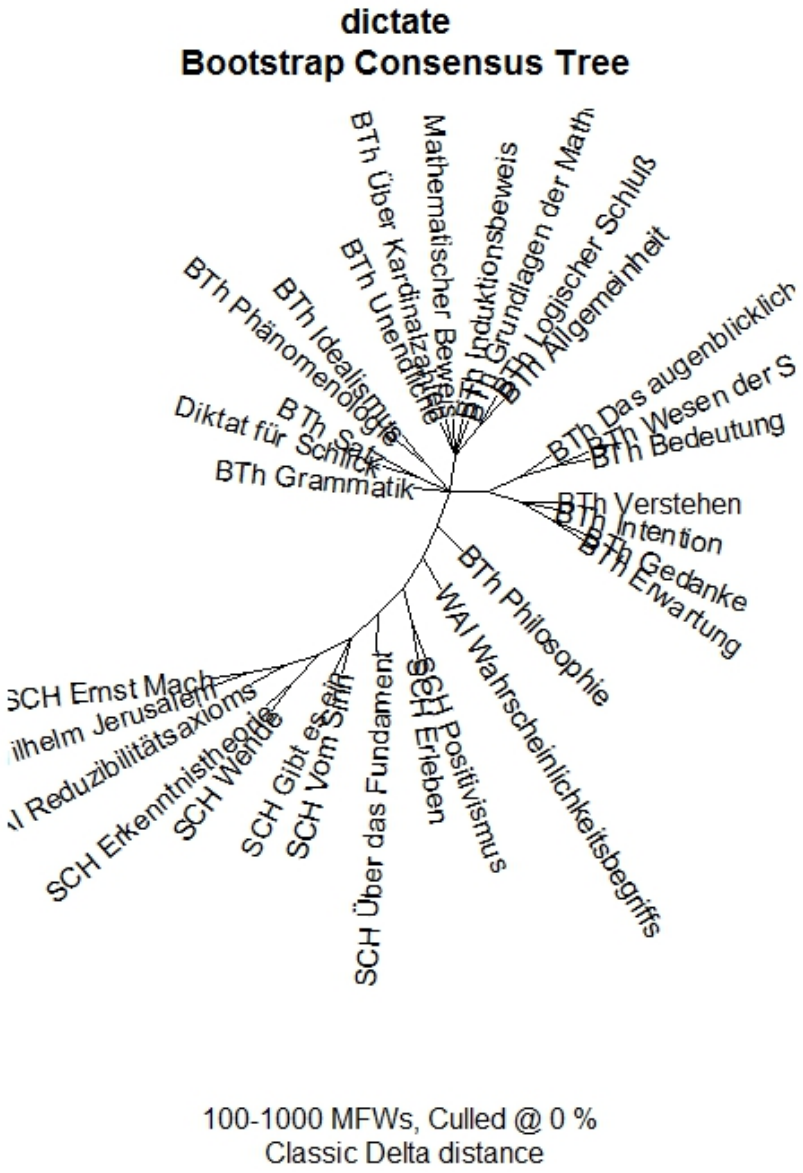

Figure 6 Bootstrap Consensus Tree for the Entire Document Set

Analysis 3. Consideration of the Dating of "Diktat für Schlick"

The answer our CS suggests for research question (2a) is thus that the "Diktat für Schlick" is probably by Wittgenstein, or if not by Wittgenstein, at least faithfully done in the style of Wittgenstein. In response to question (2b) it suggests: even if it reflects the writing style of the amanuensis, it does not suggest Waismann either more or less than Schlick and is faithfully done in the style of Wittgenstein. We can now try to find out more about the dating of the "Diktat für Schlick": (2c) In terms of chronology, what does CS tell us about where to place "Diktat für Schlick"? 1932-33 or rather later? Burrows' delta was used to determine whether "Diktat für Schlick" is closer to the original typed version of the Big Typescript (BTt) or a later version also containing handwritten annotations (BTh). Using the delta measure, the following distances were found: BTh to BTt 0.379; BTh to "Diktat für Schlick" 1.720; BTt to "Diktat für Schlick" 1.830. Thus BTh is the more similar to "Diktat für Schlick", suggesting a later date of composition for "Diktat für Schlick".

Analysis 4. Comparison of original and revised Wittgenstein texts

In this analysis we compared the individual texts comprising BTh and BTt, to see how much the corresponding text pairs differed from each other. The resulting cluster diagram is shown in Figure 8.

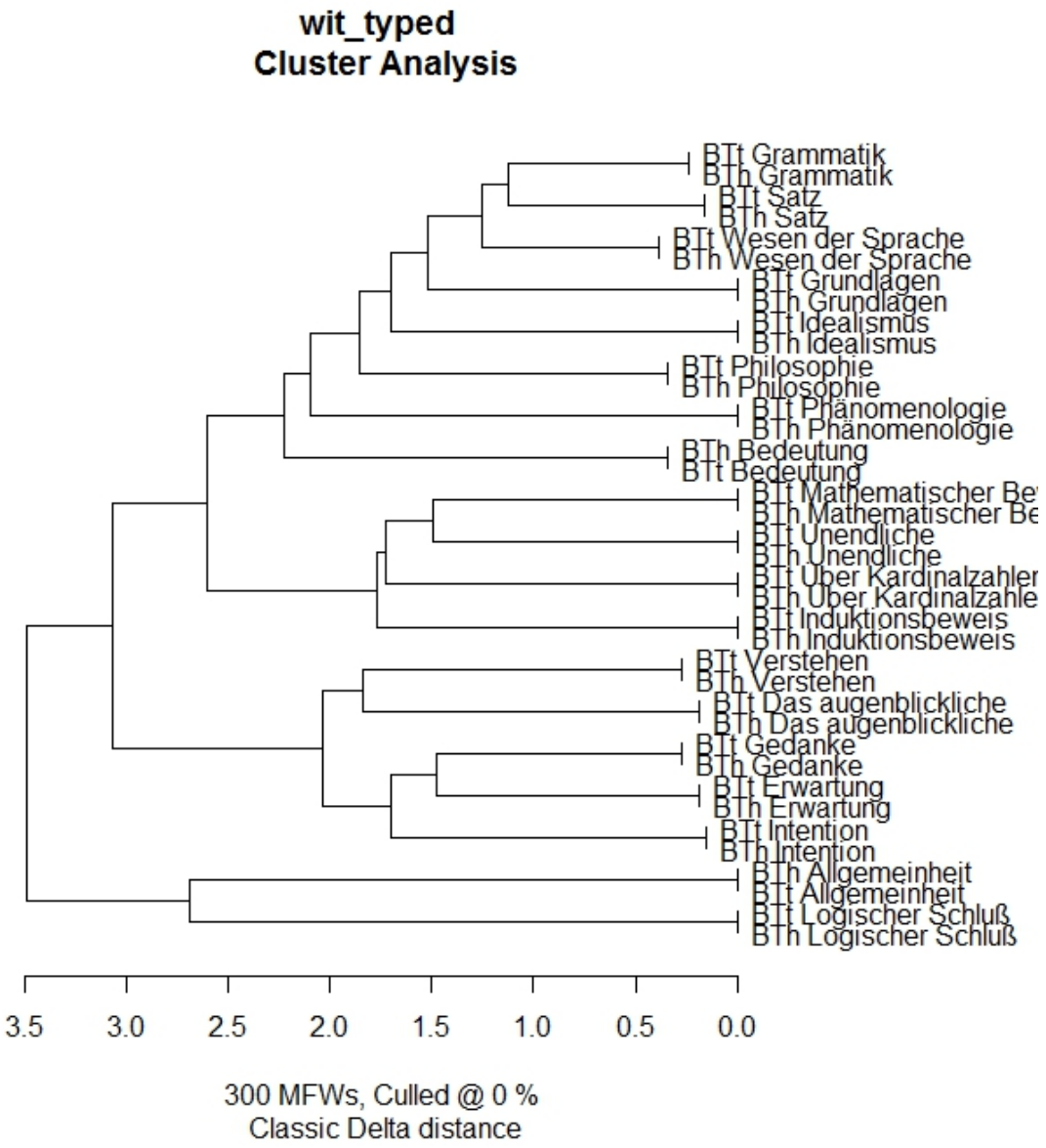

Figure 8. Cluster Analysis to compare original and annotated texts by Wittgenstein.

In every case each version pair are more similar to each other than to any of the other texts. For "Grundlagen", "Idealismus", "Phänomenologie", "Mathematischer Beweis", "Unendliche", "Über Kardinalzahlen", "Induktionsbeweis", "Allgemeinheit" and "Logischer Schluß" there is no discernible difference between corresponding versions, but for the other texts there a positive delta value was found. The corresponding text pairs with the greatest delta distance were "Wesen der Sprache", "Philosophie", "Bedeutung", "Verstehen" and "Gedanke", which all have been heavily revised.

5. Conclusion

Using techniques from computational stylometry, in particular Burrows' delta as a measure of dissimilarity between documents, and using Ward's method of hierarchical cluster analysis, multidimensional scaling and bootstrap consensus trees to visualise the results, we have given an example of how computational stylometry can be used to help answer concrete questions of Wittgenstein research, and thus to explore how computational stylometry can be applied to issues of philosophical authorship more generally. Our experiments suggest that the so-called "Diktat für Schlick" is much closer in writing style to samples of work by Wittgenstein than to samples of work by either Schlick or Waismann, and closer to the Big Typescript as it is revised in Wittgenstein's hand than to the version of typed text alone.

References

Berndt, T. J. (2002). Friendship quality and social development. *Current Directions in Psychological Science, 11*, 7-10.

Baayen, R. H. (2008). *Analysing Linguistic Data. A Practical Introduction to Statistics Using R.* Cambridge: Cambridge University Press.

Burrows, J. (2002). "Delta": a Measure of stylistic difference and a guide to likely authorship. *Literary and Linguistic Computing* 17, 3, 267–87.

Eder, M. and Rybicki, J. (2011). Stylometry with R. Poster Presented at *Digital Humanities 2011*, Stanford CA, June 19-22.

Hoover, D. L. (2011). Modes of composition in three authors. *Digital Humanities 2011*, Stanford University Library, 2011, 152-55.

Hoover, D. (2009). Modes of composition in Henry James: Dictation, style, and what Maisie knew. *Digital Humanities 2009*, University of Maryland, June 22-25, 2009.

Iven, M. (2009). Wittgenstein und Schlick. Zur Geschichte eines Diktats. In: *Stationen. Dem Philosophen und Physiker Moritz Schlick zum 125. Geburtstag*. pp. 63 – 80. Ed. F. Stadler, H. Wendel. Wien/New York: Springer.

Manninen, J. (2011). Waismann's Testimony of Wittgenstein's Fresh Starts 1931–35. In: *Friedrich Waismann - Causality and Logical Positivism*. Ed. B.F. McGuinness. Vienna Circle Institute Yearbook, Vol. 15. pp. 243-265. Dordrecht: Springer.

Opperdoes, F. (1997). *Bootstrapping*. http://www.icp.ucl.ac.be/~opperd/private /bootstrap.html . Accessed 4th May, 2012.

Rybicki, J. (2012). The Great Mystery of the (almost) invisible translator: Stylometry in Translation. In: *Quantitative Methods in Corpus-Based Translation Studies*, edited by Michael Oakes and Meng Ji, Studies in Corpus Linguistics 51, John Benjamins Publishing Co, Amsterdam, 2012, pp 231-249.

Schlick, M. (2008). Moritz Schlick Gesamtausgabe Band I/6, 2008. *Die Wiener Zeit - Aufsätze, Beträge, Rezensionen 1926-1936*. Herausgegeben und eingeleitet von Johannes Friedl & Heiner Rutte, Wien: Springer Verlag. Erkenntnistheorie und moderne Physik: 161-172; Erleben, Erkennen, Metaphysik: 33-54; Ernst Mach, der Philosoph: 61-68; Gibt es ein Materiales Apriori? : 455-469; Positivismus und Realismus: 323-362; Quantentheorie und Erkennbarkeit der Natur: 807-820; Über das Fundament der Erkenntnis: 487-514; Vom Sinn des Lebens: 99-125; Die Wende der Philosophie: 213-222; Wilhelm Jerusalem zum Gedächtnis: 137-141.

Schulte, J. (2011). Waismann as Spokesman for Wittgenstein. In: *Friedrich Waismann - Causality and Logical Positivism*. Ed. B.F. McGuinness. Vienna Circle Institute Yearbook, Vol. 15. pp. 225-242. Dordrecht: Springer.

von Wright, G. H. (1982). The Wittgenstein Papers. In: *Wittgenstein*. pp. 35-62. Oxford: Basil Blackwell.

Waismann, F. (1928). Die Natur des Reduzibilitätsaxioms. *Monatshefte für Mathematik* 35/1, 143-146.

Waismann, F. (1930). Logische Analyse des Wahrscheinlichkeitsbegriffs. *Erkenntnis* 1/1, 228-248. (Obtained from philpapers, http://philpapers.org/rec/WAILAD)

Ward, J. H. (1963). Hierarchical Grouping to Optimize an Objective Function. *Journal of the American Statistical Association* 58, 301: 236-244

Wittgenstein, L. (2000). *Wittgenstein's Nachlass: The Bergen Electronic Edition*. Ed. Wittgenstein Archives at the University of Bergen. Oxford: OUP.

Wittgenstein, L. (2009). *Wittgenstein Source Bergen Text and Facsimile Edition*. http://www.wittgensteinsource.org/. Ed. A. Pichler et al. In: Wittgenstein Source. Bergen: WAB