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# A Computational Approach to Authorship Verification of Johann Wolfgang Goethe's Contributions to the *Frankfurter gelehrte Anzeigen* (1772–73)

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## ABSTRACT

The present article proposes a stylometric computational solution for the long-standing authorship verification problem of Johann Wolfgang Goethe's anonymous 'Rezensionen' (review articles) to the *Frankfurter gelehrte Anzeigen* (*FgA*) 1772–73. Goethe was a prolific contributor to the 1772 volume of the *FgA*, which was regarded as formative for the Sturm und Drang movement. As all articles in the *FgA* were published anonymously, philological research continues to be faced with the question which Rezensionen were penned by Goethe, with only a very few of them being attributable on an unequivocal evidence basis. The idea to use stylistic and even stylometric features to attribute the *FgA* Rezensionen to contributors has been around for a while in Goethe research, but only today we have well-tested computational methods and text corpora at our disposal to actually solve the problem. In this article, we test the stylometric impostors approach against a selection of challenging *FgA* cases for a) previously clearly verified, b) controversial and c) unclear cases in order to evaluate whether the method correctly and effectively identifies Goethe as author of particular Rezensionen. Our discussion especially addresses the methodological issues that the text samples are very short for stylometric authorship verification and our evaluation in the light of our benchmarking results, the fact that some Rezensionen have been written collaboratively and that Goethe might have redacted other authors' texts. Overall, the impostors approach proved to be effective on the task to identify Goethe's stylometric fingerprint in the *FgA* 1772 Rezensionen for texts longer than 2,100 characters. While results for texts below the 2,100 characters threshold are regarded as unreliable in the context of this experiment, they may be still useful in the context of attribution arguments with caveats. The article concludes that the implemented impostor method system is suitable to be applied in an attempt to verify the authorship of all *FgA* 1772–73 Rezensionen and either confirm or reject previous attributions, or identify hitherto unknown Goethe texts in the corpus.

A COMPUTATIONAL APPROACH TO AUTHORSHIP VERIFICATION OF GOETHE'S  
CONTRIBUTIONS TO THE *FRANKFURTER GELEHRTE ANZEIGEN* (1772–73)

KEYWORDS

Johann Wolfgang Goethe; *Frankfurter gelehrte Anzeigen*; Sturm und Drang; eighteenth-century German literature; authorship attribution; authorship verification; impostors method; stylometry; digital humanities

## Introduction

Addressing the longstanding authorship attribution problem of Johann Wolfgang Goethe's (anonymous contributions to the *Frankfurter gelehrte Anzeigen* (*FgA*) of the years 1772 and 1773, the present article proposes a computational stylometric authorship verification approach as a solution. A plethora of philological research since the late nineteenth century has dealt with the question which of the *FgA*'s anonymously published 'Rezensionen' (review articles) of these two years has been penned by which author. For Goethe research this question is of specific relevance, as it is known that the author contributed an unknown number of Rezensionen to the *FgA* in 1772. There is also a so far uninvestigated possibility, claimed by Goethe himself, that he occasionally did so in 1773. Currently, the authorship of many of the anonymously published Rezensionen of the *FgA* is either unclear or their attribution has to be regarded as tentative, as in many cases philologists based their attribution on inconclusive positive philological evidence and rather vague stylistic indicators. The stylometric attribution is especially challenging due to the overall brevity of the Rezensionen, and the fact that Goethe might have redacted other authors' contributions or collaborated in so-called 'Protokoll-Rezensionen' (protocol reviews).

We present the research design for a comprehensive approach to identify all of Goethe's contributions to the *FgA* of 1772–73 using an established computational stylometric method based on the so-called impostors approach. The present article will document the method, the used parameters and corpora, as well as the authorship verification results for a range of test cases that we ran in order to prove the efficiency and accuracy of the method for the challenging *FgA* case, and discuss their interpretation. Our case study will discuss the results in the context of the research history of the *FgA* authorship attribution problem, which has seen a number of proposals of linguistic and statistical approaches since 1903.

The conducted experimental test first runs the impostors method, based on Goethe's stylometric fingerprint from his works, letters and diaries, against the set of *FgA* 1772 Rezensionen where authorship has been firmly established based on direct philological evidence. This run serves as calibration of the method, and, as importantly, demonstrates that the computational impostors approach in a blind test successfully singles out Goethe in the *FgA* 1772 solely based on stylometric signal without making use of any other contextual evidence. Second, we ran the method against a subset of the *FgA* 1772 contributions that consisted of a) samples where attribution is controversial, and has previously been subject to stylometric scrutiny utilizing an earlier, less comprehensive and well-tested stylometric approach, and b) samples that Goethe later attributed to himself, and where it is unclear how accurate his recollection was — as earlier research could establish in the past that he occasionally mistakenly attributed *FgA* Rezensionen to himself. The results will allow us to evaluate the efficiency and accuracy of the impostors approach to computational stylometry as a solution to the Goethe/*FgA* attribution problem, compare the results to previous research, and discuss specific challenges and limitations as a methodological step towards the application to the whole corpus of the *FgA* 1772–73. The purpose of this pilot study is to provide the methodological foundation for the testing of previous attributions of *FgA* articles, and for potential fresh attributions of so far unattributed *FgA* Rezensionen to Goethe on a sound methodological basis.

## Status Questionis: A Long-Standing Authorship Problem

After Johann Conrad Deinert had bought the *Frankfurter Gelehrtenzeitung* (founded 1736 by Samuel Tobias Hocker) in 1771, the intellectual and literary journal was renamed *Frankfurter gelehrte Anzeigen* and became the flagship journal of the Sturm und Drang movement in 1772, with Johann Wolfgang Goethe as contributor. The *FgA* authors vigorously engaged with the political debates of the emerging literary public of its time, in which literary journals played a key role.<sup>1</sup> Next to Goethe, the journal had a number of high-profile contributors such as the two main editors of the 1772 volume, Johann Heinrich Merck and Johann Georg Schlosser, Johann Gottfried Herder and later Karl Friedrich Bahrdt.<sup>2</sup> Goethe wrote for the *FgA* in 1772 and potentially occasionally until 1773, but the exact number and time period of his contributions are yet to be determined. The *FgA*'s so-called Rezensionen were published anonymously and often redacted by co-contributors and the editors. Some were even written collaboratively by multiple authors (Protokoll-Rezensionen).<sup>3</sup> The anonymity of the contributions was, on the one hand, a conceptual approach to enable collaboration and to guarantee the 'truthfulness' ('Wahrheit') of the contributors' opinions, avoiding the bias of authorial self-positioning and partisan group formation ('Autorfesseln und Waffenträgerverbindungen', J. H. Merck).<sup>4</sup> On the other hand, it served as a protection for the authors, especially when they touched upon religious and political issues. The owner of the journal, J. C. Deinert, was implicated in a number of religious legal complaints and lawsuits against particular contributions in the *FgA* 1772, which grew to a public legal struggle about the freedom of the press. Ultimately, Deinert was fined, but spared further damage through amnesty by the Frankfurt administration. After this conflict, the most prolific authors — among them Goethe — left the *FgA* in 1773.<sup>5</sup> Deinert's estate does not provide information that could support authorship attribution for the anonymous Rezensionen, as he destroyed submitted manuscripts for self-protection, or did not even know who the authors were.<sup>6</sup>

Therefore, Goethe philology was confronted with a problem that remained unsolved until today: the *FgA* volumes of 1772–73 comprise of 1710 journal pages-worth of anonymous Rezensionen (1772: 840; 1773: 870), of which an unknown number have been penned by Goethe. Approximately forty authors wrote, co-authored, or redacted the 396 Rezensionen of the 1772 volume alone, in most cases leaving the authorship question either unresolved or insecure. Previous authorship attribution attempts used philological arguments such as attribution, self-attribution, or hints in letters by authors or editors, and by double publications wherever possible, but in a majority of cases had to rely on the interpretation of inconclusive indicators. Attribution is further

- 1 Steffen Martus, *Werkpolitik: Zur Literaturgeschichte Kritischer Kommunikation Vom 17. bis Ins 20. Jahrhundert; Mit Studien Zu Klopstock, Tieck, Goethe Und George*, *Historia Hermeneutica*, vol. 3 (Berlin: de Gruyter, 2007); Norbert Christian Wolf, 'Heinrich Christian Boies Göttinger Musenalmanach und Johann Heinrich Mercks Frankfurter gelehrte Anzeigen: Medienkämpfe im literarischen Feld des Sturm und Drang', in *Sturm und Drang: Epoche, Autoren, Werke*, ed. by Matthias Buschmeier and Kai Kauffmann (Darmstadt: WBG, 2013), pp. 10–28.
- 2 Stefan Knödler, 'Frankfurter gelehrte Anzeigen', in *Handbuch Sturm und Drang*, ed. by Matthias Luserke-Jaqui (Berlin: de Gruyter, 2017), pp. 422–28 (p. 422).
- 3 Hermann Bräuning-Oktavio, *Herausgeber und Mitarbeiter der Frankfurter gelehrten Anzeigen 1772* (Tübingen: Niemeyer, 1966), pp. 259–66. See also Wolf.
- 4 Cited in Knödler, p. 424.
- 5 Knödler, p. 424; Hermann Dechent, 'Die Streitigkeiten Der Frankfurter Geistlichkeit Mit Den Frankfurter Gelehrten Anzeigen Im Jahre 1772', *Goethe-Jahrbuch*, vol. 10 (1889), 169–95; Hans-Dietrich Dahnke, 'Intentionen und Resultate des Jahrgangs 1772 der Frankfurter Gelehrten Anzeigen', in *Sturm und Drang: Geistiger Aufbruch 1770–1790 im Spiegel der Literatur*, ed. by Bodo Plachta and Winfried Woesler (Berlin: de Gruyter, 2015), pp. 87–99.
- 6 Wilhelm Scherer, 'Einleitung', in *Frankfurter gelehrte Anzeigen: Nachdruckausgabe*, ed. by Bernhard Seuffert (Heilbronn: Henninger 1882–83), p. lxi.

complicated by the fact that Goethe might have contributed to or redacted numerous Rezensionen by other authors, and, furthermore, reported in *Dichtung und Wahrheit* that he served as keeper of the minutes during the discussion sessions that were the basis of the collaborative Protokoll-Rezensionen.<sup>7</sup> Goethe self-attributed thirty-five of the *FgA* Rezensionen by including them in the self-edited edition of his works.<sup>8</sup> The reliability and completeness of his self-attribution though remained controversial, as it was admittedly based on vague recollection and a reconstruction effort much later in his life (according to *Dichtung und Wahrheit*).<sup>9</sup> Some of these self-attributions have later been proven wrong by research. For instance, Rezension *FgA* 1772, pp. 117–19 (45) *Über den Werth einiger deutscher Dichter* and *FgA* 1772 pp. 89–94 (33) *Allgemeine Theorie der schönen Künste*, which Goethe self-attributed in his edition of his works,<sup>10</sup> have later been attributed to Merck.<sup>11</sup> By the way, our stylometric testing confirms that these two texts have not been written by Goethe (see below, shorthand codes: Merck 02, 03). Other Rezensionen that have later been confirmed as Goethe's were left out in his *Ausgabe letzter Hand*.

The authorship of the majority of *FgA*'s Rezensionen has never been verified with systematically controlled or tested methods, despite considerable philological efforts to develop methods to attribute the texts based on philological, stylistic and linguistic features to the known, most frequent authors of the 1772–73 volumes. The comprehensive research review by Bräuning-Oktavio gives an excellent overview of the research discussion for every Rezension of the 1772 volume, and an impression of the historical instability of the attributions, which were often subject to controversy and change.<sup>12</sup> Even if direct philological evidence could establish attribution to one author, sometimes discussions arose on whether the text was actually co-authored or passages should be attributed to another author, e.g. the discussion on whether an 'Einschub' ('insertion') of the often-cited Rezension *FgA* 1772, had to be attributed to Goethe, despite Merck's authorship being confirmed by mention in one of his letters.<sup>13</sup>

In his 1865 study, von Biedermann claimed to have identified a review of *Götzens erbauliche Betrachtungen* as Goethe's that the author had not attributed to himself.<sup>14</sup> Ever since, any scholarly edition of Goethe's works has had to define which Rezensionen they would attribute to the author. A daunting task, as Georg Witkowski notes: 'With respect to the authorship of these Rezensionen we probably have to say: Ignoramus and also: Ignorabimus!'<sup>15</sup> Bräuning-Oktavio, more than seventy years later, stated that

- 7 Karin Haenelt, 'Die Verfasser Der Frankfurter Gelehrten Anzeigen von 1772: Ermittlung von Kriterien Zu Ihrer Unterscheidung Durch Maschinelle Stilanalyse', *Euphorion*, no. 78 (1984), 368–82. Bräuning-Oktavio establishes a number of thirty-seven secured and probable contributors in four 'circles' (Darmstadt, Frankfurt, Gießen, other), based in part on philological evidence and in some cases based on allusions in correspondences (Bräuning-Oktavio, *Herausgeber und Mitarbeiter der Frankfurter gelehrten Anzeigen 1772*, pp. 91–92). The estimation probably exceeds these thirty-seven because Deinet mentions that most of the authors did not know each other.
- 8 *Goethe's Werke: Vollständige Ausgabe letzter Hand*, ed. by J. W. Goethe, 40 vols (Stuttgart: J. G. Cotta 1827–30). The edition was later extended by *Goethe's nachgelassene Werke*, ed. by Johan Peter Eckermann and Friedrich Wilhelm Riemer, 20 vols (Stuttgart: Cotta, 1832–42).
- 9 Haenelt, p. 370.
- 10 *FgA* 1772, pp. 117–19 (45), *Über den Werth einiger deutscher Dichter und über andre Gegenstände den Geschmack und die schöne Litteratur betreffend*. See *Goethe's Werke*, vol. 33 (1830), pp. 3–13.
- 11 Bräuning-Oktavio, *Herausgeber und Mitarbeiter der Frankfurter gelehrten Anzeigen 1772*, p. 608, note on Rezension nos 33 and 45.
- 12 Bräuning-Oktavio, *Herausgeber und Mitarbeiter der Frankfurter gelehrten Anzeigen 1772*, pp. 593–715.
- 13 *FgA* 1772, pp. 117–19. Rezension on *Über den Wert einiger deutscher Dichter und über andre Gegenstände den Geschmack und die schöne betreffend: Ein Briefwechsel*, 1: Stück 1771. See Bräuning-Oktavio, *Herausgeber und Mitarbeiter der Frankfurter gelehrten Anzeigen 1772*, pp. 608–10.
- 14 Woldemar von Biedermann, *Goethe und Leipzig*, 2 vols (Leipzig: Brockhaus, 1865), p. 20.
- 15 Georg Witkowski, 'Einleitung', in *Goethes Werke*, vol. 26, ed by H. Düntzer, G. Witkowski, K. J. Schröer, and A. G. Meyer (Stuttgart: Cotta 1892), pp. 47–48.

his own fifty years of research on this question ultimately led him back to Witkowski's careful 'Ignoramus and also: Ignorabimus'.<sup>16</sup>

An early attempt at a linguistic, quantitative approach to this problem was made by Carl Ritter with his article in 1903.<sup>17</sup> Ritter described a method to identify authors by statistical analysis of linguistic features of their style such as orthography, adverbs and conjunctions. This effort, however, was later rebutted for its allegedly questionable choice of base texts for these features.<sup>18</sup> The psychologist Karl Marbe ventured into early experiments with quantitative linguistics and phonetics in order to discern Goethe's specific prose rhythm — without much scholarly success.<sup>19</sup> Following Ludwig Hirzel's discovery of letters confirming Goethe's authorship of two Rezensionen on Lavater and *Geßners Idyllen*.<sup>20</sup> Bernhard Seuffert, Wilhelm Scherer, and Ludwig Geiger continued to secure new attributions of *FgA* Rezensionen to Goethe using additional verification sources.<sup>21</sup> The seminal scholarly re-edition of the 1772–73 volumes of the *FgA* by Bernhard Seuffert, with an introduction by Wilhelm Scherer, made important contributions to the matter of Goethe's authorship, defining the state of the art for years to come.<sup>22</sup> The article by Otto Trieloff (1908) made scholars aware of the fact that some of the reviews could not be Goethe's, as they had to be regarded as translated re-publications from articles in contemporary English journals, first and foremost the *Gentleman's Magazine* and *Monthly Review*.<sup>23</sup>

Max Morris and Hermann Bräuning-Oktavio dedicated large parts of their academic careers to this authorship attribution question, gathering large amounts of philological evidence in a number of monographs and articles.<sup>24</sup> Where material, direct evidence for authorship attribution was missing, scholars had to rely on less conclusive grounds of attributing by notions of style and thematic preference, e.g. the recurrence of distinctive opinions, topics, phrasings ('kennzeichnende[] Lieblingswendungen')<sup>25</sup> and (allegedly) individual spelling characteristics (e.g. 'warrlich' for Schlosser, 'Schäckespear' for Goethe, etc).<sup>26</sup> Bräuning-Oktavio repeatedly criticized especially Morris for attributing *FgA* texts based on the weak evidential basis of distinctive phrasings.<sup>27</sup> In many cases, thus, attribution of *FgA* texts largely relied on either direct external evidence or low-frequency, striking lexical or thematic characteristics, the latter posing a methodological problem in themselves.<sup>28</sup>

16 Bräuning-Oktavio, *Herausgeber und Mitarbeiter der Frankfurter gelehrten Anzeigen 1772*, pp. 539 and 592.

17 Carl Ritter, 'Anwendung der Sprachstatistik auf die Rezensionen in den Frankfurter Gelehrten Anzeigen von 1772', *Goethe-Jahrbuch*, vol. 24 (1903), 185–203.

18 Hermann Bräuning-Oktavio, *Studien zu den Frankfurter Gelehrten Anzeigen vom Jahre 1882* (Gießen and others, 1911), pp. 24–25.

19 Karl Marbe, *Ueber Den Rhythmus Der Prosa: Vortrag, Gehalten Auf Dem 1. Deutschen Kongress Für Experimentelle Psychologie Zu Giessen* (Gießen: J. Ricker, 1904).

20 Ludwig Hirzel, 'Goetheana', *Im neuen Reich*, 8.2 (1878), 597–611.

21 Bräuning-Oktavio, *Studien zu den Frankfurter Gelehrten Anzeigen vom Jahre 1882*.

22 *Frankfurter gelehrte Anzeigen: Nachdruckausgabe: Mit einer Einleitung von Wilhelm Scherer*, ed. by Bernhard Seuffert, 2 vols, in *Deutsche Litteraturdenkmale des 18. Jahrhunderts in Neudrucken*, ed. by Bernhard Seuffert (Heilbronn: Henninger 1882–83). Wilhelm Scherer, 'Introduction', vol. 2, pp. iii–xc.

23 Otto Trieloff, *Die Entstehung der Rezensionen in den Frankfurter Gelehrten-Anzeigen vom Jahre 1772* (Münster: Schöningh 1908).

24 Max Morris, *Goethes und Herders Anteil an dem Jahrgang 1772 der Frankfurter Gelehrten Anzeigen* (Stuttgart: Cotta, 1909), p. 347; Bräuning-Oktavio, *Studien zu den Frankfurter Gelehrten Anzeigen vom Jahre 1882*.

25 Morris, p. 347.

26 See also Bräuning-Oktavio, *Studien zu den Frankfurter Gelehrten Anzeigen vom Jahre 1882*; and Ritter.

27 Bräuning-Oktavio, *Studien zu den Frankfurter Gelehrten Anzeigen vom Jahre 1882*.

28 Mike Kestemont, Justin Stover, Moshe Koppel, Folgert Karsdorp, and Walter Daelemans, 'Authenticating the writings of Julius Caesar', *Expert Systems With Applications*, vol. 63 (2016), 86–96, (p. 87).

In his later years, as late as 1966, Bräuning-Oktavio aimed to delineate a set of ‘typical features’ of Goethe’s style; language rhythm and melody, favourite expressions, rhetorical features such as specifics of exclamation, questions, address, double negation, accumulation and enumeration, anaphora, parenthesis, typical review beginnings, Goethe’s grammar during the ‘*Werther Periode*’, sentences omitting their verb, parallelisms, inversion, emphatic sentence endings, Latin quotes, etc.<sup>29</sup> The results of this effort — beyond the direct external proof of attribution — remained vague. But Bräuning-Oktavio already worked on a prototype of stylometry, as his private archive collection at the Technische Universität Darmstadt shows. It features a typescript on the ‘Statistik der Füllwörter in den FGA’ (‘statistics of the filler words in the *FgA*’, where filler word is a legacy linguistic term in German for function words and interjections).<sup>30</sup> The same year, Joachim Thiele published a brief description of an approach to linguistic-statistical aesthetics (‘Verfahren der statistischen Ästhetik’) with his *Untersuchung der Goethe zugeschriebenen Rezensionen in den Frankfurter Gelehrten Anzeigen mit Hilfe einfacher Textcharakteristiken*.<sup>31</sup> Four years later, Herbert Sparmann tried to distinguish Goethe’s penmanship from Merck’s by the frequency of the definite article in their writings. He detected that Merck used the definite article 40% more frequently than Goethe.<sup>32</sup> Sparmann reached his conclusion based on a very small corpus, taken only from *FgA*. The first scholar to propose a computational approach to the *FgA* authorship problem was Karin Haenelt in 1984.<sup>33</sup> Haenelt established stylistic profiles by categorizing the frequency of word functions such as nouns and adjectives, by taking into account lexicon variation and by analyzing words in first, second, and last positions in the sentence. The formulation and weight of the features are based on the hermeneutic assumption that these are the most significant for Goethe’s individual style. The study used a software tool called LDVLIB developed by Raimund Drewek, a scarcely documented, early text statistical processor.<sup>34</sup> Here as well, the base corpus of the study was very small and selective, with no control group measures in place, as again the texts were solely taken from the *FgA*.

The *FgA* volume of 1772 is a corpus of 396 anonymous Rezensionen, between one and seven journal pages in length. The articles have been penned and redacted by approximately forty authors, while there is a small number of known main contributors, amongst which was Goethe. Only for a few of the Rezensionen direct philological evidence is available to corroborate the authorship attribution. The idea that linguistic and statistical methods and style analysis might solve this problem has been around since 1903, but the projects were either short-lived or remained in a proof-of-concept state. Early attempts operated on a small *FgA* corpus basis, could not rely on independently tested methods, and a statistically computable, standard linguistic definition of style was absent. Haenelt’s study was the first to attempt to introduce computational methods, leading to interesting results despite using only a small corpus and not being able to independently test the assumptions of the features and method used.

29 Bräuning-Oktavio, *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*.

30 See [archive record at Darmstadt University Library](#), p. 9 [accessed 17 July 2019].

31 Joachim Thiele, ‘Untersuchung der Goethe zugeschriebenen Rezensionen in den Frankfurter Gelehrten Anzeigen mit Hilfe einfacher Textcharakteristiken’, *Studia Linguistica*, vol. 20 (1966), 83–85.

32 Herbert Sparmann, ‘Häufigkeitsuntersuchungen, Ein Hilfsmittel Für Den Vergleich von Texten Und Für Die Feststellung Der Verfasserschaft’, *STUF: Language Typology and Universals*, 23.1–6 (1970), 227–31 [accessed 17 July 2019].

33 Haenelt.

34 Raimund Drewek, ‘LDVLIB-Textanalyse mit System’, in *Statistik-Software 3: Konferenz über die wissenschaftliche Anwendung von Statistik-Software 1985*, ed. by Walter Lehmacher and Allmut Hörmann (Stuttgart: Fischer, 1986), pp. 283–95; and Raimund Drewek and M. Erni, ‘LDVLIB (LEM): A System for Interactive Lemmatizing and Its Application’, in *Proceedings of the Ninth International Conference on Computational Linguistics Abstracts, Coling 1982* (ACL, 1982) [accessed 17 July 2019].

Present-day computational methods for stylometric authorship attribution and verification offer significant advantages compared to earlier approaches outlined above: They have been extensively tested and benchmarked across multiple cases, with large corpora and including tests for multiple languages; The training data which constitutes the basis of the stylometric fingerprint of an author's style includes much larger corpora than ever before; The linguistic definition of style and features abstracts from the individual author: well-tested methods focus on inconspicuous, high-frequency and less variant features of an individual's style instead of low frequency features such as individual spelling or favourite phrasing.<sup>35</sup> For this project, we are in a good position to meet the method's requirements: Goethe's voluminous writings, large corpora of literary and essayistic works of the eighteenth and nineteenth century, and journal corpora of this period have been digitized.

The particular task of identifying Goethe's contributions to the *FgA* is a challenge for stylometric methodology. The Rezensionen of the *FgA* are within the typical range of 1 to 7 journal pages, ranging from ca. 130 to more than 2,100 words in length, very short for stylometric authorship verification — the sample brevity is a challenge in itself and requires careful calibration and testing.<sup>36</sup> Goethe seems to have redacted many articles, and he was involved in collaborative writing efforts, e.g. as the minutes-keeper for the collaborative 'protocol reviews'. As the Rezensionen samples were so short, we treated all texts as if authored by one person in the context of this test setup, but this factor has to be kept in mind in cases where the style signal for a text is ambiguous. The fact that Goethe was such a prolific writer is both an advantage and a challenge for the application of stylometric methods. Due to his oeuvre's broad range, its volume and extension in time, the stylometric fingerprinting might be affected by the fact that the other writers we compared Goethe's style to have been much less productive, resulting in smaller corpora than Goethe's. Additionally, his stylistic features may have changed more over time than others', as the productive literary period of his life was exceptionally long.

## Methodology: Attribution vs. Verification

In this paper, we have applied a well-known stylometric approach for computational authorship verification to the *FgA*'s Rezensionen, focusing on identifying Goethe's contributions to this corpus. Our choice for a so-called 'verification' method requires explanation. Traditionally, stylometric authorship studies have been dominated by a setup that is known as 'closed-set attribution'.<sup>37</sup> In closed-set approaches, an authorship problem is cast as a conventional classification task in text categorization. First, a standard algorithm from the field of text categorization is being trained on a set of reference documents or 'training' material, for which the authorship is uncontested. The authorship of these documents is considered to consist of class labels, or a series of mutually exclusive categories to which each document belongs. Next, for evaluation purposes, the trained algorithm is applied to a set of previously unseen test documents (or 'held out items') that have to be attributed to one of the candidate categories. The

35 Kestemont and others, 'Authenticating the writings of Julius Caesar', p. 87.

36 Maciej Eder, for instance, claimed that the minimum sample length for stable results lies between 2,500 (for Latin) and 5,000 (for English, German, etc) words, 'Does Size Matter? Authorship Attribution, Small Samples, Big Problem', *Literary and Linguistic Computing*, 30.2 (2015), 167–82 [accessed 17 July 2019].

37 An excellent survey of the field of computational authorship studies can be found in Efstathios Stamatatos, 'A Survey of Modern Authorship Attribution Methods', *Journal of the American Society for Information Science and Technology*, 60.3 (2009), 538–56.

attribution results can then be compared against the ground truth for the test documents, which allows us to assess the performance of such a classifier.

This kind of simulation in closed-set attribution tasks is meant to approximate the real-life situation where an anonymous document has to be attributed to one of a series of previously known author candidates. Naturally, the caveat associated with this type of simulation – which is often compared to a line-up situation — is that this does not correspond to many real-world scenarios: often it cannot be guaranteed that the actual author of an anonymous document is among the author candidates that the classification has analyzed during training. Recently, the field of stylometry has, therefore, turned its attention towards more demanding, but also more realistic experimental setups.<sup>38</sup>

Open-set attribution is the experimental setup where attribution algorithms can no longer assume that the author of a test document is necessarily among the available set of candidate authors (which is often true for historical case studies). Regarding classification, this setup is essentially identical to the attribution problem, but it introduces an additional classification option: ‘none of the above’ (i.e. the label which is applicable in the case that an anonymous document cannot be assigned to any of the known candidate authors). An open set attribution problem can therefore be decomposed into a finite set of binary questions: for each candidate author, we wish to estimate the probability that they authored an anonymous text under scrutiny. If a certain probability threshold is exceeded for a given author, the text can then be attributed to that author. Because this setup explicitly allows for a text to remain unattributed, it is to be preferred in historical cases of disputed authorship, where no ground truth is available. Because our specific focus, we have casted the *FgA* problem as a verification task for a single candidate author, namely Goethe — i.e. a single binary problem from an open-set attribution task. Below, we describe our approach in greater detail. [All code and data](#) necessary to reproduce our experiments are available without restrictions.

The impostors method described below will always compare an unknown document to two sets of documents:<sup>39</sup> those by the candidate author under scrutiny (Goethe in our case) and those by a large set of similar documents by so-called ‘impostor’ authors. This comparison will yield a so-called verification score, bounded between 0 and 1, that can be interpreted as the probability that Goethe, rather than another writer, authored the anonymous document. Crucially, this system needs to be calibrated by determining a threshold for this verification score: when the score for an anonymous document exceeds this threshold, the system indicates to accept Goethe’s authorship, based on the stylometric signal; if not, it indicates to reject it.

These scores, however, need to be evaluated with regard to the material, contextual, and methodological limitations. For instance, collaborative authorship and editorial redaction, long quotes or OCR artefacts may lower the stylometric signal of an author in a text sample. Heavy-handed editing may indicate the redactor as author. For very short text samples, the verification method may not produce stable results, which is the reason why careful prior testing and calibration is critical in the *FgA* case. It has to be

38 See, in particular, the recent work by Justin Stover and others, ‘Computational Authorship Verification Method Attributes a New Work to a Major 2nd Century African Author’, *Journal of the Association for Information Science and Technology*, no. 67 (2016), 239–42 [accessed 17 July 2019].

39 Kestemont and others, ‘Authenticating the writings of Julius Caesar’; Mike Kestemont, Els Stronks, Martine de Bruin, and Tim de Winkel, ‘Did a Poet with Donkey Ears Write the Oldest Anthem in the World? Ideological Implications of the Computational Attribution of the Dutch National Anthem to Petrus Dathenus’, in *Digital Humanities 2017, Conference Abstracts*, ed. by ADHO (2018) [accessed 17 July 2019]; Moshe Koppel and Yaron Winter, ‘Determining If Two Documents Are Written by the Same Author’, *Journal of the Association for Information Science and Technology*, 65.1 (2014), 178–87; Greta Franzini, Mike Kestemont, Gabriela Rotari, Melina Jander, Jeremi K. Ochab, Emily Franzini, and others, ‘Attributing Authorship in the Noisy Digitized Correspondence of Jacob and Wilhelm Grimm’, *Frontiers in Digital Humanities*, vol. 5 (2018) [accessed 17 July 2019].

noted that the setup and calibration of the system, which is based on statistical methods, is always an effort of trying to find the parameters that deliver the best-balanced accuracy trade-off between precision and recall. As a result, for instance, a system's best calibration setting may make it better at being very sure when indicating a particular individual as the author of a text sample (high precision score) than at correctly indicating all samples written by this individual in the corpus (high recall score).

## Data: Corpora

### *Goethe corpus*

The Goethe training corpus consists of the Goethe subsection of the literary TextGrid corpus, with a few manual additions.<sup>40</sup> This corpus includes prose, drama, poetry, and essays from all phases of his production (20.3 MB text sample data). It furthermore includes the collection of Goethe's letters to others (28.6 MB text sample data), and diaries (8.2 MB text sample data). The TextGrid corpus of Goethe's work is not as comprehensive as the complete edition of his work (e.g. the *Sophienausgabe*), but with approximately 2/3 its size it provides a good representation of Goethe's style. The TextGrid corpus has the advantage that it is a high text quality corpus, and free of OCR artefacts. The inclusion of Goethe's letters and the diary corpora, also retrieved from TextGrid, provides an additional resource to represent the author's average style fingerprint across genres.

### *Impostors corpus*

The impostors corpus has to consist of texts that are not by Goethe and not part of the queried test corpus (the *FgA* texts to be tested), which serve as 'distractors'. It should include text samples by the authors we want to distinguish Goethe's style signal from. Therefore, we chose verified texts by Herder (10.3 MB text sample data, TextGrid), Merck (171 kb text sample data, TextGrid), and Schlosser (2.8 MB text sample data, own OCR, with artefacts) which have not been published in *FgA* for our impostors corpus. We furthermore included a large corpus from the Deutsches Textarchiv (German Text Archive), consisting of contemporary sources (1700–1850) from newspapers, and science and humanities publications (569.8 MB text sample data).<sup>41</sup> The Deutsches Textarchiv corpus is a high text quality corpus, and free of OCR artefacts.

### *Calibration corpus*

For the calibration phase, we have compiled the forty-four *FgA* 1772 articles for which the authorship has been so far confirmed beyond reasonable doubt by direct philological evidence, according to Haenelt and Bräuning-Oktavio, who also cited the evidence.<sup>42</sup>

This calibration corpus contains six verified Rezensionen by Goethe, eight by Herder, ten by Höpfner, one by Leuchsenring, five by Merck, eight by Petersen, two by Raspe, four by Schlosser. These samples have been OCRed from *FgA* scans, the OCR results were manually corrected and are nearly free of OCR artefacts.

40 The *Goethe corpus* is a subcorpus of the TextGrid literary text corpus [accessed 17 July 2019]. We used version II of this corpus, accessible under this link. The corpus is licensed CC BY 3.0.

41 *Deutsches Textarchiv* [accessed 17 July 2019]. The tagged corpus is licensed CC BY-NC 3.0. The raw text corpus, which we used, is public domain [accessed 17 July 2019].

42 Haenelt; Bräuning-Oktavio, *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*, pp. 593–715.

For technical reasons, we have set a minimum length of 2,100 characters (including space characters) for inclusion of texts in the calibration corpus. Our observation showed that below this minimal threshold the results of the method are not sufficiently reliable for calibration.

On this basis, ten verified texts (one by Goethe, seven by Höpfner, one by Petersen, one by Schlosser) have been excluded from the calibration corpus, leaving 34 verified *FgA* texts for calibration of the method. The verification results of the remaining ten verified short texts below the 2,100-character length limit will be discussed separately with a small corpus of other shorter texts from the *FgA* 1772 that needed testing.

Johann Wolfgang Goethe (1749–1832)

Rezensio	Number <sup>43</sup>	Short title	Shorthand code
<i>FgA</i> 1772 342–43	156	<i>Leben und Charakter Herrn Christian Adolph Klotzens</i>	goethe 01
<i>FgA</i> 1772 537–40	246	<i>Moralische Erzählungen und Idyllen von Diderot und S. Geßner</i>	goethe 02
<i>FgA</i> 1772 555–58	255	<i>Gedichte von einem polnischen Juden</i>	goethe 03
<i>FgA</i> 1772 697–701	328	<i>Aussichten in die Ewigkeit, in Briefen an Zimmermann</i>	goethe 05
<i>FgA</i> 1772 830–32	396	<i>Nachrede statt der versprochenen Vorrede</i>	goethe 04

Johann Gottfried Herder (1744–1803)

Rezensio	Number	Short title	Shorthand code
<i>FgA</i> 1772 265–69	116	<i>F. D. Michaelis Mosaisches Recht</i>	herder 01
<i>FgA</i> 1772 425–50	197	<i>Staatsveränderungen von Italien</i>	herder 02
<i>FgA</i> 1772 471–72	218	<i>Hans der Schufficker; Die Pilgrimme von Mecca; Röschen und Colas; der Zauberer: Vier Singspiele aus dem Französischen mit Musik</i>	herder 08
<i>FgA</i> 1772 473–78	219	<i>A. L. Schlötzers Vorstellung seiner Universalhistorie</i>	herder 03
<i>FgA</i> 1772 481–86	222	<i>J. Sal. Semleri Paraphrasis Evangelii Johannis</i>	herder 04
<i>FgA</i> 1772 505–09	231	<i>I. D. Michaelis Versuch über die siebenzig Wochen Daniels</i>	herder 05
<i>FgA</i> 1772 609–14	282	<i>Bemerkungen über den Unterschied der Stände in der bürgerlichen Gesellschaft von Job. Millar Esq.</i>	herder 06
<i>FgA</i> 1772 665–69	314	<i>James Beattie Versuch über die Natur und Unveränderlichkeit der Wahrheit</i>	herder 07

43 The Rezensionen will be referred to with their original page numbering (*FgA* 1772 pp.) and the Rezension number as referred to by Bräuning-Oktavi, *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen* 1772, pp. 593–715.

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Ludwig J. F. Höpfner (1743–97)

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 244–46	100	<i>Karl Philipp Kopp, ausführliche Nachricht von der älteren und neueren Verfassung der geistlichen und Zivilgerichte</i>	höpfner 02
<i>FgA</i> 1772 585–87	269	<i>Collectionis notabiliorum Decisionum supremi tribunalis appellationum Hasso-Cassellani</i>	höpfner 07
<i>FgA</i> 1772 750–51	351	<i>Johann Heumann von Teutschenbrunn, Rechtlicher Katechismus</i>	höpfner 09

Franz Michael Leuchsenring (1746–1827)

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 65–70	25	<i>H. L. Gaubii, Adversariorum varii argumenti</i>	leuchsenring 01

Johann Heinrich Merck (1741–91)

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 57–61	21	<i>Klopstock Oden</i>	merck 01
<i>FgA</i> 1772 89–94	33	<i>Allgemeine Theorie der schönen Künste</i>	merck 02
<i>FgA</i> 1772 117–19	45	Über den Werth einiger deutscher Dichter	merck 03
<i>FgA</i> 1772 340–42	155	<i>Der Schmetterling, nebst drey Liedern von Joh. Georg Jacobi</i>	merck 04
<i>FgA</i> 1772 726–28	340	<i>Musen-Almanach</i>	merck 05

Georg Wilhelm Petersen (1744–1816)

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 33–40	15	<i>Heilige Reden von Christoph Friedrich Sangerhausen</i>	petersen 01
<i>FgA</i> 1772 273–74	119	<i>Leß, Dr. Gottfr. Lehre der christlichen Mäßigkeit und Keuschheit</i>	petersen 02
<i>FgA</i> 1772 417–19	190	<i>Schulz, Bibliothek der vorzüglichsten englischen Predigten</i>	petersen 03
<i>FgA</i> 1772 518–19	236	<i>Hirtenbrief S. H. G. des Bischofs von Speyer</i>	petersen 04
<i>FgA</i> 1772 593–96	274	<i>Sammlung verbesserter und neuer Gesänge</i>	petersen 05
<i>FgA</i> 1772 601–02	278	<i>Predigten nach dem Geschmack der drey ersten Jahrhunderte</i>	petersen 07
<i>FgA</i> 1772 607–08	281	<i>Lobrede auf den Meßias von Christian Bachholm</i>	petersen 08

## Rudolf Erich Raspe (1736–94)

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 458–62	213	<i>Joseph Fuchs, Alte Geschichte von Mainz</i>	raspe 01
<i>FgA</i> 1772 463–64	214	<i>Job. Thaddäus, De Germanorum veterum aviditate bibendi</i>	raspe 02

## Johann Georg Schlosser (1739–99)

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 486–87	223	<i>Fragen an Kinder, eine Einleitung in die Religion</i>	schlosser 02
<i>FgA</i> 1772 522–26	239	<i>J. C. Lavater, Von der Physiognomik</i>	schlosser 03
<i>FgA</i> 1772 549–51	251	<i>Libri Elementaris Pars I</i>	schlosser 04

*Test corpus*

After calibrating the system, we applied it to a number of controversial and challenging cases. Our goal was to benchmark the method against previous research, especially regarding short text samples and cases known to be ambiguous in previous stylometric attribution attempts.

The *test corpus* contains a) four text samples from the *FgA* 1772 longer than 2,100 characters which could not be securely attributed by research on a direct philological evidential basis and have therefore been tested and discussed by Karin Haenelt with her linguistic approach.<sup>44</sup> b) four disputed texts (one of them potentially a Protokoll-Rezension: 346), which are longer than 2,100 characters and have not been tested by Haenelt.

## Controversial cases tested by Haenelt

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 591–92	273	<i>Cymbelline, ein Trauerspiel</i>	fga 01
<i>FgA</i> 1772 141–44	51	<i>Empfindsame Reisen durch Deutschland</i>	fga 02
<i>FgA</i> 1772 745–49	350	<i>Essays on song-writing: with a collection of such Englis[c]h Songs</i> (The review itself written in German.)	fga 03
<i>FgA</i> 1772 801–07	380	<i>Die schönen Künste in ihrem Ursprung</i>	fga 04

## Controversial cases, other

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 233–36	95	<i>Westphals, [...], Versuch einer systematischen Erläuterung</i>	fga 05

44 Haenelt.

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<i>FgA</i> 1772 141–44	100	<i>Kopp, [...], ausführliche Nachricht von der älteren und neueren Verfassung der geistlichen und Zivilgerichte</i>	fga 06
<i>FgA</i> 1772 277–79	122	<i>Braun, Versuch in prosaischen Fabeln und Erzählungen</i>	fga 07
<i>FgA</i> 1772 740–42	346	<i>Allgemeine deutsche Bibliothek</i>	fga 08

In a separate set, we have tested the challenging texts that were shorter than 2,100 characters, in order to tentatively evaluate whether despite the fact that we regard the results below 2,100 characters as not reliable, they may still serve as ‘weak’ indicators for attribution, in combination with other evidence. This set consists of the ten verified Rezensionen we excluded from the calibration corpus (see above), two controversial cases discussed by Haenelt<sup>45</sup>, and five other controversial texts (54, 67, 81, 84, 107).<sup>46</sup>

Rezension	Number	Short title	Shorthand code
<i>FgA</i> 1772 808	382	Über das von dem Herrn Prof. Hausen entworfne Leben des H. G. R. Klotz	goethe 06
<i>FgA</i> 1772 230–31	92	<i>Jo. Henr. Nob. de Berger Oeconomia iuris</i>	höpfner 01
<i>FgA</i> 1772 279–80	123	<i>Kritisches Wörterbuch über juristische Sachen</i>	höpfner 03
<i>FgA</i> 1772 311	140	<i>Otia in otio minime otiosi</i>	höpfner 04
<i>FgA</i> 1772 383–84	174	<i>Freyherrn von Kreittmayrs Grundriß</i>	höpfner 05
<i>FgA</i> 1772 419–20	191	<i>Johann Heinrich Fricke, ordentlichen Lehrers der Rechte auf der Universität Kiel</i>	höpfner 06
<i>FgA</i> 1772 743	347	<i>Sicherer Testamentmacher</i>	höpfner 08
<i>FgA</i> 1772 765	360	<i>Dr. August Friedrich Schott Entwurf einer juristischen Encyklopädie</i>	höpfner 10
<i>FgA</i> 1772 599–600	277	<i>Cramer, Wetzlarische Nebenstunden</i>	petersen 06
<i>FgA</i> 1772 457–58	212	<i>Götzens erbauliche Betrachtungen über das Leben Jesu auf Erden</i>	schlosser 01
<i>FgA</i> 1772 215–16	85	<i>Ein Päckchen Satyren aus Oberdeutschland</i>	fga 09
<i>FgA</i> 1772 151	54	<i>Journal für die Liebhaber der Literatur</i>	fga 10
<i>FgA</i> 1772 176	67	<i>Thrasylbulus. Oder von der Liebe zum Vaterlande</i>	fga 11
<i>FgA</i> 1772 207	81	<i>Die Jägerin, ein Gedicht</i>	fga 12

45 Haenelt, p. 85.

46 *FgA* 1772 151 (54); 176 (67); 207 (81); 214–15 (84); and 255–56 (107).

<i>FgA 1772</i> 214–15	84	<i>Vermischtes Magazin eine Wochenschrift</i>	fga 13
<i>FgA 1772</i> 255–56	107	<i>Wie soll ein junges Frauenzimmer sich würdig bilden?</i>	fga 14

## Preprocessing

The mean text length in the calibration corpus amounted to 5,454 characters after cleaning. We have therefore divided all longer texts in the reference corpus and impostors corpus into equal-sized, consecutive slices of 5,454 characters each. For the Goethe material, this yielded 6,372 slices, and for the impostors corpus 90,531. Note that Goethe is strongly outnumbered in terms of corpus size, in comparison to the impostors, which introduces a mild bias against Goethe in our setup. This bias can nevertheless be considered healthy in terms of the precision of the system: while our focus firmly lies with Goethe, we do not want to rush into attributing texts to him either.

We converted each document into a numeric vector using a traditional bag-of-words approach, focusing on two feature types: tokens  $n$ -grams and characters  $n$ -grams.<sup>47</sup> We extracted the 50,000 most frequent tokens unigram (single tokens) and bigrams (two consecutive tokens) from Goethe’s reference works, as well as the 50,000 most frequent character trigrams and tetragrams in them. ( $N$ -grams are overlapping sequences of e.g. four characters long that are extracted via windowing over the text, e.g. for the sentence, ‘we extract’, the first tetragrams would be ‘we e’, ‘e ex’, ‘ext’, ‘extr’, and so on.) In our model, we represent each document through counting how often these vocabulary items appear in the slice, followed by a normalization that gives more weight to document-specific vocabulary items.<sup>48</sup> Finally, the 50,000 features for the token and character  $n$ -grams are concatenated to represent each document as a feature vector of 100,000 values.

## Calibration and Testing, Verification

For the impostors algorithm, we proceed as follows: during a fixed number of iterations ( $n=500$ ), we compare an unknown document to a random selection of twenty-five documents from Goethe’s collection and twenty-five randomly impostor texts. We then randomly select 50,000 (i.e. 50%) of the feature columns that we have at our disposal. We calculate the cosine distance between the anonymous text and the  $2 \times 25$  randomly sampled documents from both collections: finally, we record whether the anonymous text’s ‘nearest neighbour’ was a Goethe document or an impostor document. At the end of this procedure, the verification score is taken to be the ratio of iterations in which a Goethe document was selected as the nearest neighbour. If the text was by Goethe, this number would ideally be close to one; if not, the ratio should ideally approximate zero. The sampling of features in each iteration captures the intuition that evidence of common authorship should be stable enough to be visible across different random samples of the vocabulary. The sampling of documents, on the other hand, from both

47 Fabian Pedregosa, Gaël Varoquaux, Alexandre Gramfort, Vincent Michel, Bertrand Thirion, Olivier Grisel, and others, ‘Scikit-Learn: Machine Learning in Python’, *Journal of Machine Learning Research*, vol. 12 (2011), pp. 2825–30.

48 As in previous work (Kestemont and others, ‘Authenticating the writings of Julius Caesar’; and Kestemont and others, ‘Did a Poet with Donkey Ears Write the Oldest Anthem in the World?’), we made use of a conventional TF-IDF weighting scheme to reinforce the weight of less frequently occurring, significant tetragrams.

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the Goethe and impostors collection ensures that the verification approach goes beyond the superficial (i.e. topical) similarity that might exist between the unknown document and a specific set of texts in the reference data.

Below is a visualization of the result of applying this procedure to the texts of undisputed authorial provenance in the calibration dataset. The bars represent individual texts, coloured by authorship (Goethe vs non-Goethe), and indicate the verification score for each text. Note that the verification scores are invariably higher for Goethe's texts than for the other documents, only a fraction of which obtain scores that near the verification scores for Goethe's texts. For this calibration set of the previously verified texts from the *FgA* 1772 that are longer than 2,100 characters, the impostor method successfully distinguishes Goethe's stylometric fingerprint from the other well-known authors in *FgA* 1772, without using any other information than the described stylometric data.

More quantitatively, we observe that a threshold of  $\sim 0.60$  gives us the highest F1-score (1.00) on this calibration material: this means that in order to maximize the performance of our system, we should only accept Goethe's authorship for *FgA* texts that in more than  $\sim 60\%$  of the 500 iterations were closer to Goethe than to an impostor (The F1-score is a more technical variant of plain accuracy, that takes into account the fact that not every author is equally well represented in the calibration material.) This calibration threshold for the verification score serves as an importance baseline in interpreting the results obtained for the test sets below.

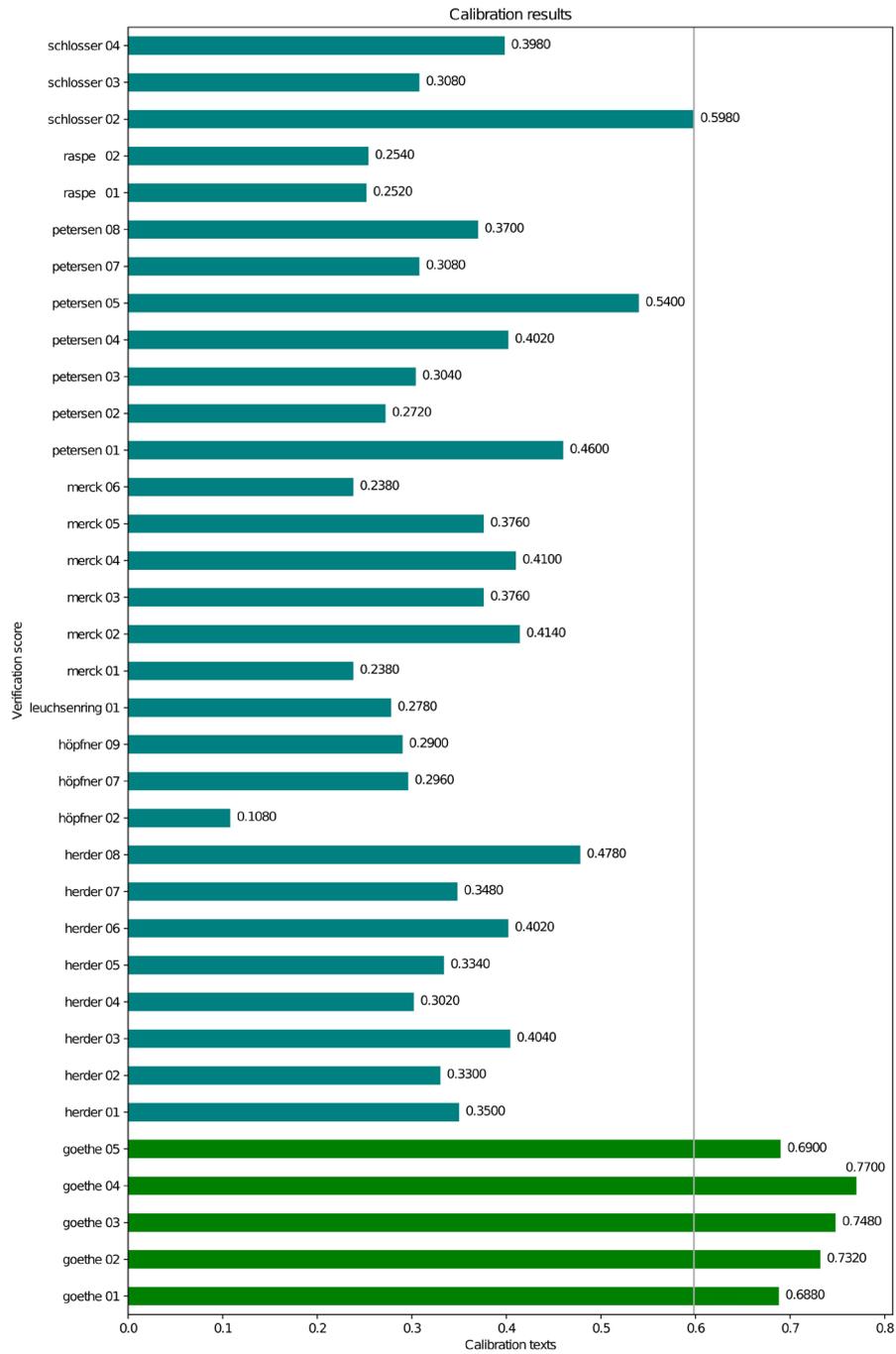


Fig. 1 Calibration set results for texts from FgA 1772 where authorship is regarded as verified (green for Goethe, petrol for other verified authors).

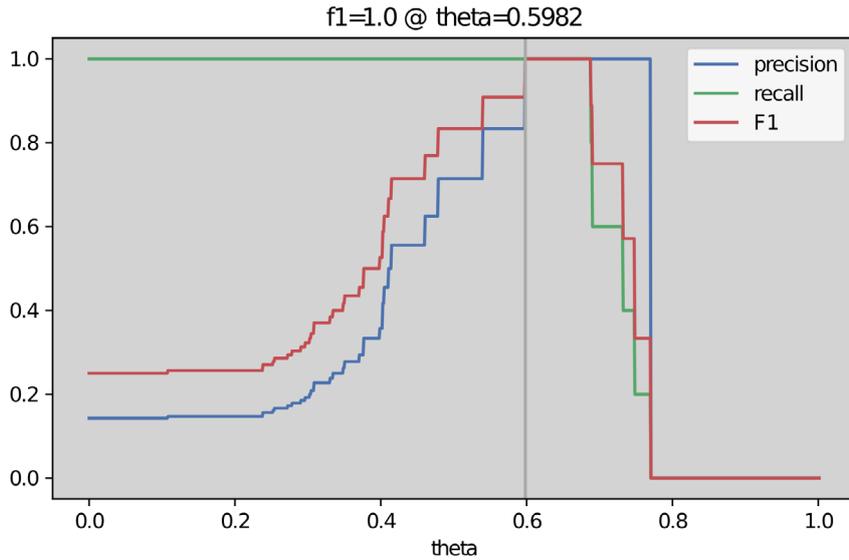


Fig. 2 Precision, recall, F1 graph for the calibration set run for verified texts from FgA 1772. F1 is a measure of accuracy, balancing precision and recall (harmonic mean).

### Previous Stylometric Research on *FgA 1772*: Haenelt

One focus of our analysis is a selection of five texts that Haenelt marked as previously unattributed, suggesting an attribution by her own linguistic features. Two of the Rezensionen are especially challenging, as one of them is close to our minimum length cut-off (fga 01: 2,171), two significantly shorter than 2,100 characters (fga 05: 1,165, petersen 06). One of these is a text sample that we assumed to be verified as being penned by Goethe, according to Bräuning-Oktavio (petersen 06), and excluded from the calibration set due to its brevity, has been tested and discussed by Haenelt as a contested case. This sample will be discussed separately in the section on short text samples.

Rezension	Number	Short title	Claimed by Goethe	Length in char, incl. spaces	Shorthand code
<i>FgA 1772</i> 591–92	273	<i>Cybelline, ein Trauerspiel</i>	Yes	2,171	fga 01
<i>FgA 1772</i> 141–44	51	<i>Empfindsame Reisen durch Deutschland</i>	Yes	7,014	fga 02
<i>FgA 1772</i> 745–49	350	<i>Essays on song-writing: with a collection of such Englis[c]h Songs</i>	No	7,857	fga 03
<i>FgA 1772</i> 801–07	380	<i>Die schönen Künste in ihrem Ursprung</i>	Yes	11,110	fga 04
<i>FgA 1772</i> 215–16	85	<i>Ein Päckchen Satyren aus Oberdeutschland</i>	No	1,165	fga 09
Haenelt tested and discussed as unclear:					
<i>FgA 1772</i> 599–600	277	<i>Cramer, Wetzlarische Nebenstunden</i>	No	1,272	petersen 06

Based on her own score matrix of five Goethe-specific features (i.e. average sentence length [words/syllables], vocabulary composition and distribution, sentence transition position, sentence last position, sentence second position), Haenelt's results for her closed-set test based on a *FgA*-only corpus were as follows:

Rezension	Number	Short title	Feature match author profile	Attribution according to Haenelt
<i>FgA</i> 1772 591–92	273	<i>Cybelline, ein Trauerspiel</i>	2 x Merck 2 x Herder 1 x Goethe	An ambiguous case, she decided Herder is most probable.
<i>FgA</i> 1772 141–44	51	<i>Empfindsame Reisen durch Deutschland</i>	4 x Goethe 1 x Herder	Highest probability: Goethe.
<i>FgA</i> 1772 745–49	350	<i>Essays on song-writing: with a collection of such Englis[c]h Songs</i>	5 x Herder	Positive: Herder.
<i>FgA</i> 1772 801–07	380	<i>Die schönen Künste in ihrem Ursprung</i>	5 x Goethe	Positive: Goethe.
<i>FgA</i> 1772 215–16	85	<i>Ein Päckchen Satyren aus Oberdeutschland</i>	3 x Goethe 2 x Herder	Ambiguous: Goethe or Herder
<i>FgA</i> 1772 599–600	277	<i>Cramer, Wetzlarische Nebenstunden</i>	5 x Goethe 1 x Herder	Highest probability: Goethe.

By running the implemented impostor method against these, we intend to compare the methods, test how consistent the results are with the results of previous stylometric approaches, and whether the results differ significantly.

### Application to *FgA* 1772 Rezensionen where Authorship Is Contested, Discussion of Results

After calibrating the system, we applied it to a test set of anonymous texts, for which authorship could not be established based on direct philological evidence. We focused on the test set of texts longer than 2,100 characters, as described above, which includes four text samples discussed by Haenelt and four other unverified texts. Goethe self-attributed four of them (*fga* 01, 02, 04, 07), although his ascriptions remained controversial. Bräuning-Oktavio proposed to regard *fga* 08 (346) as a Protokoll-Rezension collaboratively written by Goethe, Merck, Petersen, and Wenck.<sup>49</sup> The texts vary in length in the range of two to seven *FgA* pages (2,171–11,111 characters).

In the bar chart below, we plot the verification scores which can be obtained from applying the slice dropout setup: the bars show the proportion of Goethe and non-Goethe attributions during 250 iterations. The score can be interpreted as a probability measure, indicating the robustness of attribution for each text sample to Goethe. The grey line indicates the attribution threshold of ~0.6 that was determined in the calibration step.

49 Bräuning-Oktavio, *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*, p. 702.

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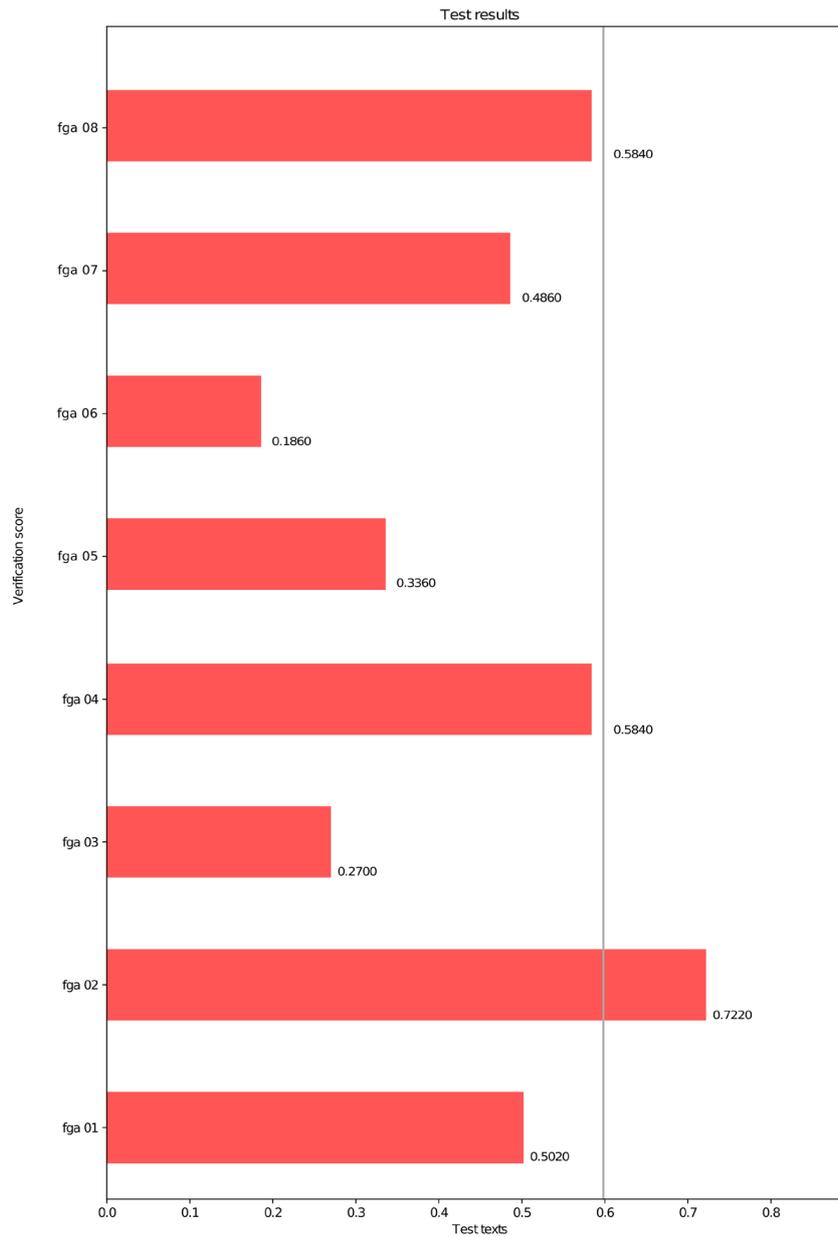


Fig. 3 Test set results for sample texts from FgA 1772 longer than 2100 characters where authorship is regarded as not verified, disputed or unclear (red).

The following table shows our results for fga 01–04 compared to Haenelt’s, to schematize and compare the confidence of our results with hers.

Rezension	Number	Haenelt		Kestemont, Martens, Ries		Shorthand code
		Feature match author profile	Attribution according to Haenelt	Score	Interpretation and attribution according to KMR	
<i>FgA</i> 1772 591–92	273	2 x Merck 2 x Herder 1 x Goethe	An ambiguous case, she decided Herder is most probable.	Verification probability: 0.5	Borderline case: it does not reach the attribution threshold for Goethe (0.6), but scores fairly high (0.5).	fga 01
<i>FgA</i> 1772 141–44	51	4 x Goethe 1 x Herder	Highest probability: Goethe.	Verification probability: 0.72	Clear result: Goethe.	fga 02
<i>FgA</i> 1772 745–49	350	5 x Herder	Positive: Herder.	Verification probability: 0.27	Clear result: not Goethe.	fga 03
<i>FgA</i> 1772 801–07	380	5 x Goethe	Positive: Goethe.	Verification probability: 0.58	Borderline case. Scratches (0.58) on the attribution threshold for Goethe (0.6).	fga 04

Haenelt came to her results based on her score matrix of five, somewhat more intuitive features: Average sentence length, vocabulary composition and distribution, sentence transition position, sentence last positions, sentence second position. From the above table and the bar chart, it can be concluded that we come to similar results compared to Haenelt’s findings. Like Haenelt, our system clearly rejects Goethe as the author of *Essays on song-writing* (fga 03). Likewise, it also identifies Goethe as the author of *Empfindsame Reisen durch Deutschland* (fga 02).<sup>50</sup> Similar to Haenelt, it suggests with high probability that Goethe is also the author of *Die schönen Künste in ihrem Ursprung* (fga 04), with a score very close to the attribution threshold. It is possible that three longer blockquotes from Sulzer’s book in this Rezension lower the score below the threshold in this case. As formally authorship is rejected by the current system, further

50 This result has to be read with the caveat that the text includes long quotes from the reviewed book *Empfindsame Reisen durch Deutschland* by Johann Gottlieb Schummel. In another test, where the *FgA* text sample was cleaned up a bit more, it even reached a score above 0.8. This high score is possibly an effect of Goethe’s preference to polemicise about Schummel’s work by ridiculing his figure ‘Yorick’/‘Yorik’ or, as he calls him in *Wilhelm Meisters Wanderjahre*: ‘Yorick-Sterne’, also quoting directly and indirectly from Schummel’s texts. It is probably a matter of interpretation whether this has to be regarded as thematic bias of the method by a corpus effect or a supporting argument for the attribution to Goethe.

detailed testing with another impostor system that compares the text sample not only to Goethe's stylometric fingerprint, but also to that of the other known authors of *FgA* 1772 as candidates, is advised to yield conclusive results.

The result for *Cymbelline* (fga 01) is also similar to Haenelt's. It is a borderline case, but suggests a different conclusion: While Haenelt's criteria point to either Merck or Herder with equal scores (2 score points each), there is also one score point for Goethe. She then — without a clear argument — decides to state that Herder is the most probable candidate. With 0.5 as a score for Goethe in our approach, the threshold for attribution to Goethe would not be reached, but we regard the score as too high in relation to others to reject Goethe's authorship at this point. With the caveat in mind that the length of fga 01 is just above the minimum length, we would suggest cross-verifying fga 01 using an impostor system that compares the text specifically to the stylometric fingerprints of Herder and Merck as candidates. If Herder happens to score equally high as Goethe in such a test, this might be an indicator for a collaboration between the two authors in this case. This would seem plausible given the spelling of 'Schäckespear', usually regarded as typical for Goethe, and the contextual fact that Herder had just, early 1772, finished the second version of his famous Shakespeare-article, published in 1773.<sup>51</sup>

This possibility is especially relevant in the light of the almost erratic attribution history of *Cymbelline*. Goethe attributed the text to himself; Scherer and Biedermann confirmed this attribution, but Trieloff saw both Goethe's and Merck's style in the text, while Morris decided in favour of Herder's authorship. Bräuning-Oktavio concluded in 1966 that it must be Goethe, mainly based on content-arguments and the spelling of 'Schäckespear'.<sup>52</sup> Haenelt, finally, overrules this intuition again in favor of Herder, relying on an early version of stylometry to exclude Goethe, while her reasoning to rule out Merck was not made explicit.

Regarding the other four cases that Haenelt does not discuss, we got some interesting results: fga 05 and 06 have not been self-attributed by Goethe, Bräuning-Oktavio attributed them mainly to Höpfner, with a possible contribution to the text by Goethe. The attribution scores of our system for these two texts agrees with Bräuning-Oktavio's hypothesis, they indicate that the author is not Goethe (fga 05: 0.34; fga 06: 0.19).

When it comes to fga 07, it has been self-attributed by Goethe and Bräuning-Oktavio tends to confirm this self-attribution,<sup>53</sup> but the stylometric signal score for Goethe in this text does not reach the attribution threshold (although it is higher than fga 05 and 06). This is a borderline case that needs more specific testing with the other authors as candidates.

A highly interesting case is fga 08, as it was marked as a collaborative Protokoll-Rezension by Bräuning-Oktavio, which in 1966 he attributes equally to Goethe, Merck, Petersen, and Wenck<sup>54</sup> — probably due to its bullet-point structure which resembles short notes. Wilhelm Scherer and Georg Witkowski were both sure to see Goethe's style in this text, Morris assumed Herder as author, earlier (in 1912) Bräuning and Morris assumed Merck. Our impostor system suggests Goethe as author with a score of 0.58, just below the attribution threshold, with the same score as fga 04. We therefore suggest

51 Franz Zinkernagel, *Herders Shakespeare-Aufsatz: Mit Anmerkungen herausgegeben von F. Z.* (Bonn: Marcus und Weber Verlag, 1912), p. 2.

52 Bräuning-Oktavio, *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*, pp. 526 and 528.

53 Bräuning-Oktavio, *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*, p. 634.

54 Bräuning-Oktavio, *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*, p. 702.

that Goethe is a strong candidate for authorship for this Rezension and further specific testing should be conducted to either confirm or reject his authorship.

### **Exploring the Limits: (Very) Short Texts**

Our so far successful application of the impostor method to the *FgA* 1772 case is already stretching the limits of the method, which normally requires larger text samples for reliable results. Quite a number of the Rezensionen in the *FgA* are actually even shorter than 2,100 characters, which is why we ran the method also against a set of texts that was even shorter than 2,100 characters, in order to evaluate whether the method might still produce unreliable, yet maybe useful results. The good news is that all texts in the sample group verified for other authors than Goethe did not reach the attribution threshold, but stayed far below:

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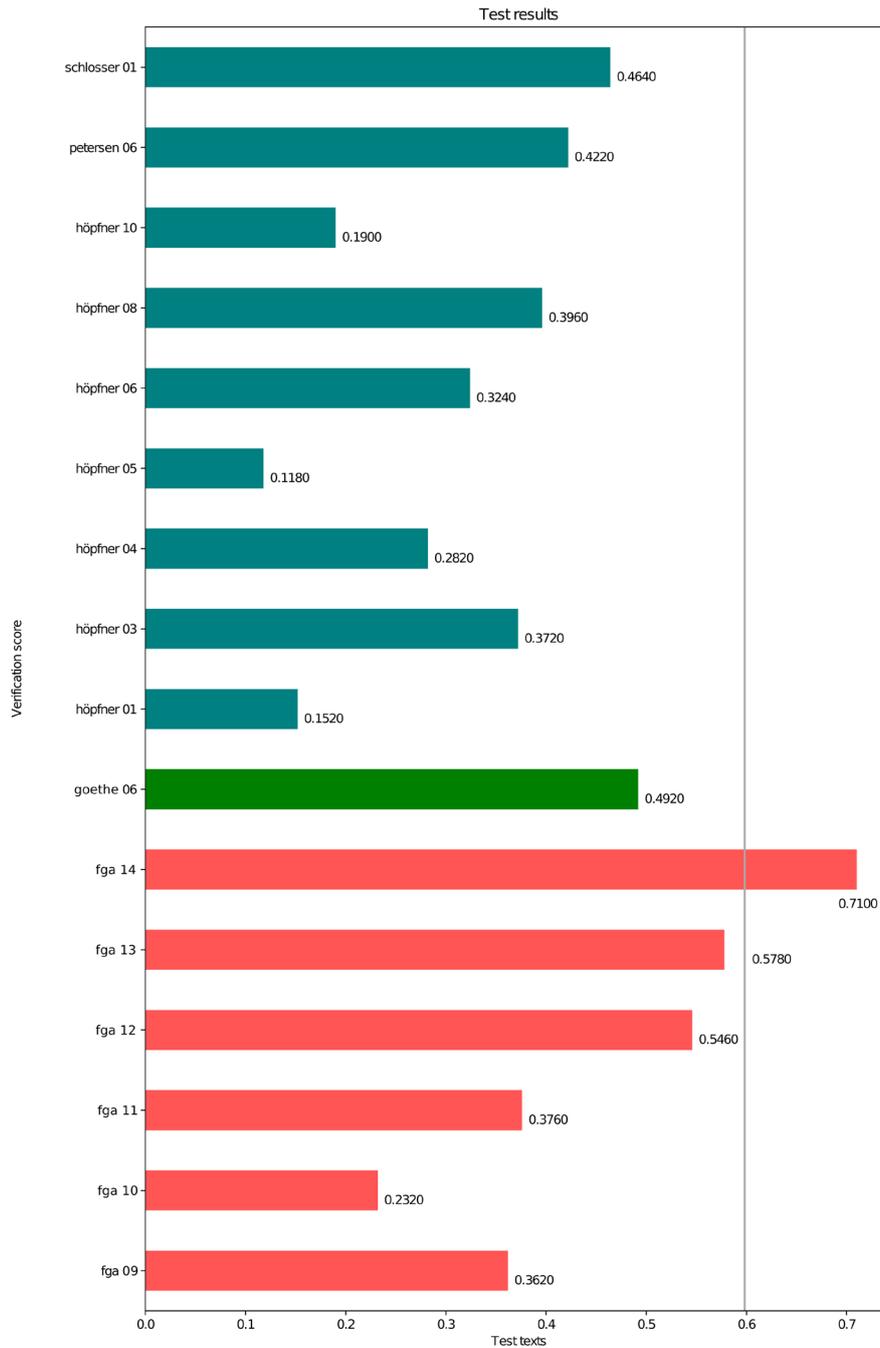


Fig. 4 Test set results for sample texts from FgA 1772 shorter than 2100 characters where authorship is regarded as either verified (green for Goethe, petrol for Höpfner and Petersen) or not verified, disputed or unclear (red).

Among the group of verified texts below 2,100 characters, none reached the attribution threshold — also not the Rezension goethe 06, which is regarded as a confirmed Goethe text. This is not hard to explain: goethe 06 is with 1,352 characters extremely short and contains a quote from the reviewed book of 93 characters. If one then subtracts the bibliographical information at the start of each Rezension from the text, it seems plausible that a text this short with quotes does not reach the threshold

— even though it had the highest stylometric score among the group of verified short texts. Thus, this low score does not necessarily reject Goethe's authorship.

In this group is also the text *petersen 06*, which we regarded as verified with Bräuning-Oktavio, and which has been tested by Haenelt with the suggestion with 'high probability' that it was written by Goethe. With 1,272 characters, this Rezension is surely too short for any definitive stylometric attribution, and the resulting score of 0.42 does not suggest any specific Goethe signal. But again, with a text this short, this test is not a conclusive reason to reject his authorship either.

Haenelt has also tested *fga 09* as a controversial text. With 1,165 characters, this Rezension is also very short. Haenelt comes to the conclusion that Goethe or Herder must have written it. The fairly low impostor method score of 0.36 certainly does not suggest it was Goethe, with the caveat that the text is too short for a clear verification or rejection.

For *fga 10* and *11*, Bräuning-Oktavio suggests Goethe as author,<sup>55</sup> while the scores seem not to support this hypothesis (*fga 10*: 0.23; *fga 11*: 0.38). Contrary to this result, *fga 12*, *13*, and *14* scored very high (0.55–0.71), *fga 14* even reaching attribution threshold. Goethe attributed *fga 12* to himself in his works, so this seems plausible; *fga 13* has been attributed to Goethe by Bräuning-Oktavio as well (in accordance with Scherer and Seuffert, while others guessed Herder and Merck).<sup>56</sup> The Goethe style signal in *fga 14*, which has also been attributed to Goethe by Bräuning-Oktavio, seems to be strong enough (0.71) to hypothetically suggest Goethe as an author and test this hypothesis further against Herder and Merck who were the other candidates suggested by Morris and Goedeke.<sup>57</sup>

## Conclusions

Considering the status of Goethe as one of the most important authors of German literature and world literature, it is striking that previous research did not reach a consensus on the authorship attribution question concerning his Rezensionen in the *FgA* of 1772–73. Our article traced the research tradition of this authorship attribution problem, indicating that despite the fact that linguistic, style identification and even early stylometric methods came into the view of philologists since 1903, none of the discussed approaches has been rigorously applied to the whole corpus and involving large-scale corpora. These early proof-of-concept studies often used intuitive definitions of style, relied on closed-set approaches and operated on a limited corpus set defined by the *FgA* itself and few isolated style examples taken from elsewhere in Goethe's works. Bräuning-Oktavio, Thiele, and Sparmann proposed 'simple text characteristics' such as word frequency of definite article and expletives as stylistic markers to solve the authorship attribution problem, but did not reach a generalized, consistent definition of linguistic style markers. Sparmann was the first to apply such a linguistic method to a very small, *FgA*-only corpus, finding that texts by Merck might be distinguishable from Goethe's by his more frequent use of the definite article. Karin Haenelt's study was the first to propose computational methods and put them to work on a small number of test cases, based on a *FgA*-only corpus, yet her linguistic definition of Goethe's stylistic features was not tested and lacked methodological foundation. With the recent innovations in computational stylometric authorship verification research,

55 Bräuning-Oktavio *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*, pp. 612 and 618.

56 Bräuning-Oktavio *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*, p. 624.

57 Bräuning-Oktavio *Herausgeber und Mitarbeiter Der Frankfurter Gelehrten Anzeigen 1772*, p. 629.

a new, open-set road to solving the problem can be taken which utilizes a generalized and well-tested definition of stylistic features that is being trained on large corpora.

In our blind test trial run, the stylometric impostor authorship verification method proved to be effective to confirm the attribution of known Goethe Rezensionen in the *FgA*, clearly distinguish Goethe's style fingerprint from others', as well as largely confirm results for controversial and unattributed cases achieved by Haenelt's closed-set study, with small improvements. This proves that the results of the impostor approach are stable enough even for such small text samples as most of the *FgA* Rezensionen, as they are consistent with previous philological evidence and at least comparable with earlier, less developed attempts at stylometric solutions to the *FgA* problem. In the course of this survey, we started applying the system to controversial cases in *FgA* 1772 where no linguistic attribution attempts have been made and tentatively tested, discussed the possibility whether — with the necessary caveats — the impostor approach could even yield in some cases useful, if not conclusive, results for Rezensionen shorter than 2,100 characters.

Methodologically, this is a large step forward, as the stylometric authorship verification approach as an open-set approach takes into account that the tested texts might have been penned by one of the almost 40 other authors, and is — for the first time in research on the *FgA* problem — based on a well-tested linguistic style model and is trained on a large corpus that is not *FgA*.

We conclude this essay with an assessment of what our trial run means for future research on Goethe's contributions to *FgA* and what can be expected of the future application of this method. Our results suggest that in this blind test, the applied stylometric method performed effectively to verify Goethe's authorship in clear, confirmed cases, as well as in cases known to be problematic, with our method appropriately reflecting the lower certainty of the latter. We successfully defined the limits of accuracy and reliability of the current system.

This result indicates reasonable accuracy and is particularly encouraging in the light of the fact that the Rezensionen of *FgA* are relatively short. As a result, we can conclude that it would be promising to subject all Rezensionen of *FgA* 1772–73 to the same test, which was beyond the scope of this article.

In view of periodical studies in general, digitization of large periodical and newspaper corpora enables computational stylometric authorship verification for anonymous articles and texts where authorship might be obfuscated or in doubt due to unknown or misleading initials, pseudonyms, or censorship evasion. Doing authorship verification at scale on periodicals would enable researchers to trace the activity of canonical authors and reconstruct the evolution of writers' networks across periodicals more accurately. Beyond periodical research, mass digitized and high-quality periodicals corpora may in combination with authorship verification methods also serve to establish the authorship of unattributed or misattributed texts that may have been anonymously published in books, political leaflets or anonymous documents found in archives, e.g. letters or manuscripts.

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