

Did Shakespeare Write *Double Falsehood*? Identifying Individuals by Creating Psychological Signatures With Text Analysis

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Abstract

More than 100 years after Shakespeare's death, Lewis Theobald published *Double Falsehood*, a play supposedly sourced from a lost play by Shakespeare and John Fletcher. Since its release, scholars have attempted to determine its true authorship. Using new approaches to language and psychological analysis, we examined *Double Falsehood* and the works of Theobald, Shakespeare, and Fletcher. Specifically, we created a psychological signature from each author's language and statistically compared the features of each signature with those of *Double Falsehood*'s signature. Multiple analytic approaches converged in suggesting that *Double Falsehood*'s psychological style and content architecture predominantly resemble those of Shakespeare, showing some similarity with Fletcher's signature and only traces of Theobald's. Closer inspection revealed that Shakespeare's influence is most apparent early in the play, whereas Fletcher's is most apparent in later acts. *Double Falsehood* has a psychological signature consistent with that expected to be present in the long-lost play *The History of Cardenio*, cowritten by Shakespeare and Fletcher.

Keywords

language, thinking, individual differences, LIWC, personality, cognitive complexity

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In 1728, Lewis Theobald published a play titled *Double Falsehood*. In presenting this work, he reported that it was based on three original manuscripts of a play that he had discovered, all written by Shakespeare. At the time, Theobald had published extensively on Shakespeare's work and was an avid collector of playwright manuscripts. Unfortunately, Theobald's original manuscripts are believed to have been lost in a library fire (Carnegie & Taylor, 2012). The authorship underlying *Double Falsehood* has now been contested for centuries (Dominik, 1991), with scholars having offered evidence of the play being written either by Shakespeare or by Theobald himself (see Hammond's, 2010, edited work *Double Falsehood* for a thoughtful set of analyses).

Double Falsehood is particularly interesting because later scholars found references to a similarly themed play, presented in London in 1613, called *The History of Cardenio* and attributed to Shakespeare and John Fletcher. Before his death in 1616, Shakespeare

coauthored at least two other plays with Fletcher, *Henry VIII* and *Two Noble Kinsmen*. In the current research, we used new techniques combining contemporary authorship identification (AID) methods with the psychology of language to infer who wrote *Double Falsehood*.

Authorship Identification: A Brief Primer

Historically, scholars have used many AID methods. Perhaps the most well-known methods are those referred to as stylometry (Holmes, 1994). Traditional stylometry is based on the assumption that language patterns are acquired idiosyncratically; as a result, each person uses

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words and word patterns uniquely (van Halteren, Baayen, Tweedie, Haverkort, & Neijt, 2005). In early applications of stylometry, scholars examined basic language features, including spelling (Craig, 1999; Wellman, 1936), vocabulary (Johnson, 1996; Ule, 1982), and complexity (Fucks, 1952; Morton, 1978). Viewed as clues about authors' personalities, cultures, and experiences, these variables shaped hypotheses about unknown authors' identities. However, such stylometric methods were of limited usefulness when considered individually (Grieve, 2007).

The first computer-based stylometric analysis was applied to 11 of the 84 Federalist Papers by Mosteller and Wallace (1964). The authorship of the 11 papers was disputed, and by comparing function-word use, Mosteller and Wallace concluded that all were written by one particular author who had written the majority of the other Federalist Papers as well (see Juola, 2006, and Pennebaker, 2011). Despite the apparent success of the computer-based approach in this and other studies, AID methods often provide only probabilistic clues as to a document's authorship.

The Psychology of Language

Although dozens of quantification methods exist, those linked to AID often focus on patterns of individual words (i.e., unigrams) and phrases (e.g., bigrams, trigrams, etc.; see Koppel, Schler, & Argamon, 2008). However, words can also be classified along hundreds of psychological dimensions, including cohesion, time orientation, and sentiment, to name a few. From a psychological perspective, perhaps the most basic distinction among words is the distinction between content and function words (e.g., Miller, 1995). Function words include conjunctions, prepositions, and other words that typically express grammatical relationships (e.g., articles, negations). In the English language, there are relatively few common function words, yet they account for the majority of written and spoken words (Pennebaker, Mehl, & Niederhoffer, 2003). Recent studies have found that function words reveal much about psychological and social processes, including emotional state, cognitive complexity, and sociability. (See Tausczik & Pennebaker, 2010, for a detailed discussion of links between function words and social-psychological processes.)

However, most of the English vocabulary consists of content words. Content words reveal psychological information in a more transparent way than function words, conveying the who, what, when, where, why, and how of mental life. For example, people may convey negative emotions with words of anger or anxiety (e.g., Pennebaker, 2004). More securely attached people tend to use more words related to inclusion (Cassidy, Sherman, & Jones, 2012). A message's content can indicate a person's

culture and time (e.g., Leigh, 2011), and more socially connected people make more social references in their self-concepts (Burke & Dollinger, 2005). Even one's pre-occupations (e.g., food, drinking, sex) are often apparent in the content of one's language, which is predictive of later behaviors (Robinson, Navea, & Ickes, 2013).

An important point is that language use is consistent within person across time and context (Mosteller & Wallace, 1964; Pennebaker, 2011; Pennebaker & King, 1999). We highlight two primary implications of this:

- A person can be mapped onto multiple psychological dimensions simultaneously via his or her unique language.
- This psychological mapping will be relatively stable across time and context for most individuals.

In sum, function and content words simultaneously reflect the many different psychological patterns and processes particular to the individual.

The Current Study: Creating a Psychological Signature of the Individual

In the current study, we bridged the gap between the field of AID and current psychological understandings of language by using language-derived *psychological signatures* as a means of differentiating individuals. At the heart of modern AID is a loosely grouped assortment of procedures known as machine learning (see Koppel et al., 2008). *Machine learning* refers to techniques whereby computers are taught to discriminate between outcomes or categories. For example, a computer can be trained to make difficult medical diagnoses on the basis of what symptoms are—and are not—present (Kononenko, 2001). These techniques can even identify faces and objects with unsettling accuracy (Viola & Jones, 2004). Such discriminative power has obvious appeal to scholars seeking to solve questions of authorship.

Although machine-learning procedures use multiple measures to demarcate outcomes, they have not been applied to explicitly psychological interpretations of language. By considering multiple psychological dimensions of a person's language simultaneously, it is possible to create a psychological signature of that person. This high-dimensional composite of a person's mental life represents the dimensions along which he or she thinks, feels, and engages with the world in a way that is uniquely his or her own. Such representations of people's mental worlds not only differentiate individuals, but also provide powerful clues as to how they differ from one another in specific and fundamental psychological terms.

We examined the curious case of *Double Falsehood*, a play of disputed origins, by applying new language analytic techniques to identify the psychological signatures of the likely authors of this play. Using four new methods and one traditional method of AID, in combination with modern classification procedures, we explored how those signatures compared with a psychological signature fashioned from *Double Falsehood*. In this article, we interpret our results and discuss their convergence with observer reports and life outcomes, as well as their implications for understanding the individual's mental world in relation to others'.

Method

Preparation of the language samples

Previous scholars (see Hammond, 2010) have proposed that the three most likely authors of *Double Falsehood* are Shakespeare, Fletcher, and Theobald. Texts from each author were acquired from various sources. The resulting 55 texts used for analyses consisted of 33 plays by Shakespeare, 9 by Fletcher, 12 by Theobald, and *Double Falsehood*; with the exception of the latter, all are plays that are generally believed to have been written in solo (see the appendix for a list of the plays; for further information on the sample, see Supplemental Material A in the Supplemental Material available online). Each text was manually stripped of extraneous information that did not directly reflect the author's language (e.g., publication information such as the title and author's name, the list of *dramatis personae*, and appendices). Stage directions were left intact.

All cleaned texts were processed through software designed specifically to convert idiosyncratic and outmoded spellings to their U.S. equivalents (e.g., "threat'ning" to "threatening," "prithee" to "pray thee"; for a complete list, see Boyd, 2014c). Although the conversion process was by no means exhaustive, it improved analytic reliability, both within and between authors. Copies of all modified text files are available from the authors of this article.

Language quantification

In the current research, we used what is referred to as a word-counting approach to quantify the language in the texts. With this approach, an index for a language category is expressed as a percentage indicating that category's prominence relative to the language in the whole document. A word-counting approach to language assessment can seem superficial. For one thing, it ignores context: A word often has different meanings in different situations. For example, a person can say the same sentence in a

genuine, ironic, or sarcastic manner, thereby conveying completely different word meanings. Also, word counting is viewed by some researchers as being prone to error because a given word can inherently have different meanings (e.g., Schwartz, Eichstaedt, Dziurzynski, et al., 2013). The word *depressed*, for example, can variously refer to sadness, an economic condition, or even the physical state of an object.

These are valid criticisms when considering single words or sentences. We took a broader view, however, and adopted a probabilistic model (e.g., Harris, 1954). Consider, for example, that statistically speaking, the majority of times when people use the word *depressed*, they are referring to the psychological condition. Moreover, a truly melancholic person will tend to use a variety of other depression-related words (Ramirez-Esparza, Chung, Kacwicz, & Pennebaker, 2008). Our chief quantification procedure capitalized on these human tendencies. Specifically, we used text analysis programs, Linguistic Inquiry and Word Count (LIWC; Pennebaker, Booth, & Francis, 2007) and RIOT Scan (Boyd, 2014b), to calculate the percentage of words in each text that belonged to particular language dimensions of interest.

Function-word measures. High-frequency function words are commonly used as variables in AID studies (see Koppel et al., 2008). However, there are eight overarching classes of function words: personal pronouns, impersonal pronouns (e.g., *it, any, thing*), articles, prepositions, auxiliary verbs, conjunctions, negations, and high-frequency adverbs lacking direct referents (e.g., *very, really, so*). These eight classes of function words have been shown to reflect separate psychological processes through their use (Tausczik & Pennebaker, 2010). The total percentage of function words in nontechnical texts averages around 52% to 60% (Pennebaker, Chung, Ireland, Gonzales, & Booth, 2007); in the current sample, the average rate of function-word use was 53.4%. By quantifying the use of these eight function-word classes in *Double Falsehood*, we were able to explore how likely it was that each of the three candidate authors contributed to the thinking style of the play. Additionally, this procedure allowed us to identify unique psychological characteristics typical of each of the three candidate authors.

The categorical-dynamic index and other measures of complexity. Factor analyses of function words across all types of text typically have revealed a single dimension of language use that is called the categorical-dynamic index (CDI; Pennebaker, Chung, Frazee, LaVergne, & Beaver, 2014). The CDI is a continuum along which any text necessarily falls and reveals psychological

characteristics of its author, including how categorically complex the author's thinking is. People whose writing is at the categorical (high) end of the continuum tend to use nouns, articles, and prepositions at high rates. A closer inspection of categorical texts indicates that people whose writing scores high on this dimension tend to be analytic or formal in their thinking. This means that they tend to classify objects, people, and events in hierarchical ways. People high in categorical thinking tend to be emotionally distant and often take problem-solving approaches to everyday situations.

At the other end of the CDI dimension are people whose writing is characterized by high rates of auxiliary verbs, pronouns, adverbs, and the other function-word categories—in other words, dynamic (rather than categorical) language. People who are dynamic thinkers tend to live more in the here-and-now and like to tell stories, and are often more focused on social matters relative to categorical, complex thinkers (see Supplemental Material B and Pennebaker, 2011, for more details and an overview of the distinction between categorical and dynamic thinking).

In the current research, we examined categorical complexity of all the texts along with two other conventional measures of complexity that have been used in past AID and psychological research: average sentence length and the use of large words. As are function-word composite measures like the CDI, measures of sentence length and word length are psychologically meaningful from a cognitive perspective (e.g., Guastella & Dadds, 2006), and both measures are quite reliable (Pennebaker & King, 1999).

Content-word measures. We analyzed content words in two ways. First, we determined the rates of content-word categories in the texts by relying on the default content categories of the computer program LIWC. Second, as we describe in the next section, we relied on a meaning-extraction technique to inductively identify themes within the plays.

In the same way that a text can be scanned for the eight classes of function words, it can be scanned for well-established categories of content words. The default LIWC 2007 dictionary (Pennebaker, Booth, & Francis, 2007) codes for words that belong to more than 40 content categories, including words related to positive and negative emotions, family members, sensory perceptions, religion, and death. This dictionary is the most widely used in psychology (Schwartz, Eichstaedt, Kern, et al., 2013), and its psychometric properties have been extensively validated across time, location, and even multiple languages (e.g., Pennebaker, Chung, et al., 2007).

The meaning-extraction method. Within the past decade, a number of computerized methods that allow

researchers to automatically extract “themes” from large bodies of text have been developed. After these themes have been extracted, their presence in a text can be measured by calculating the number of times words from each theme appear as a percentage of the total number of words in the text. One technique for extracting themes that has emerged from the field of psychology is called the meaning-extraction method, or MEM (Chung & Pennebaker, 2008). Applying the MEM procedure to all the plays using specialized software (see Boyd, 2014a) resulted in the identification of 13 broad themes. We then measured the presence of these themes in *Double Falsehood* and the works of Shakespeare, Fletcher, and Theobald using word-counting software (Boyd, 2014b).

For some themes, two or more of the plays (including plays written by a single author and plays written by different authors) were virtually indistinguishable on average. For example, all three authors (generally speaking) used very similar, relatively low rates of words from the “family structure” theme. However, when we looked at each author in total, something akin to a signature began to arise. By combining statistics for all the themes across all of a given author's works, we were able to arrive at a more general thematic signature for the three candidate authors. Just as one's personal signature tends to be a little different every time it is written and depends on the type of document signed (e.g., a birthday card vs. a business document), a thematic signature exhibits variations from piece to piece. Yet as do other content categories, the categories of a thematic signature exhibit reliability across time. The relative presence or absence of a given theme can be a useful cue to an individual's psychological characteristics (Chung & Pennebaker, 2008; Ramirez-Esparza et al., 2008). Supplemental Material C contains additional discussion, information, and statistics relevant to the MEM and our use of it in this project.

Traditional stylometric measures: linguistic “tells.”

In high-stakes poker, experts frequently analyze the ways in which their opponents laugh, speak, or fidget when they are concealing a particularly good (or very bad) hand. The belief is that people have subtle tells—specific behaviors that reveal their anxiety or excitement. A similar idea has been used by stylometrists and other language experts in AID. Specifically, many writers tend to use idiosyncratic words and phrases across their writings. Just as various authors (and people in general) use different function words at different rates, they also differ in their use of relatively uncommon words and phrases (e.g., Craig & Kinney, 2009). For example, Foster (1996) was able to identify the anonymous author of *Primary Colors* as Joe Klein in part because of the way Klein consistently used relatively obscure adverbs (e.g., *goofily*, *bandily*, *buffily*, *juicily*) in his newspaper and magazine

Table 1. Results for Each Language Measure, by Classification Technique

Measure	LDA		J48 DT		SMO SVM	
	Best candidate	<i>p</i> (%)	Best candidate	<i>p</i> (%)	Best candidate	<i>p</i> (%)
Function-word classes	Shakespeare	91.4	Shakespeare	96.8	Shakespeare	83.3
CDI, WPS, large words	Shakespeare	61.0	Shakespeare	93.1	Shakespeare	78.9
LIWC content categories	Theobald	97.3	Shakespeare	97.1	Shakespeare	75.4
Thematic signatures	Shakespeare	100	Shakespeare	97.1	Shakespeare	99.8
Low-base-rate tells	Shakespeare	83.8	Shakespeare	100	Shakespeare	97.1

Note: The probabilities listed in the table are best-candidate probabilities for the linear discriminant analyses (LDAs) and prediction margins for the J48 decision trees (DTs) and sequential minimal optimization support vector machines (SMO SVMs). CDI = categorical-dynamic index; LIWC = Linguistic Inquiry and Word Count; WPS = words per sentence.

articles as well as in *Primary Colors*. A traditional stylistic technique, then, is to identify words that are used at a low rate in the general population but used consistently by a selected author across a series of published works.

The psychology of low-base-rate tell words is rather different from that of thinking style or content. As mentioned earlier, how people speak and what they speak about reveal basic psychological tendencies about their thinking, perceptions of the world, and connection with others. Use of low-base-rate words is less psychologically meaningful. Often, use of these words likely reflects people's chance experiences that pertain to language learning in the family and school or to personal aesthetics (e.g., Colman, Walley, & Sluckin, 1975). Shakespeare might have used the word *behalf* simply because he liked the sound of it. Fletcher may have sprinkled the word *handsomely* into most of his plays because an admired protégé used the word. Although the use of low-base-rate words is not likely to be deeply psychological, such words can be clues to authorship because of the consistency with which they emerge. Therefore, we examined the texts in our sample to identify each author's low-base-rate tell words (for additional information, see Supplemental Material D).

Analytic approach

Although there are dozens of classification procedures that fall under the umbrella of supervised machine learning and have been used in AID (see Juola, 2006, and Koppel et al., 2008, for reviews), we focused on three: linear discriminant analysis (LDA), decision trees (DTs), and support vector machines (SVMs; see Supplemental Material E for additional discussion of all three methods). (Descriptive statistics for all measures, and a naive conceptualization of distance for readers unfamiliar with our statistical approaches, are presented in Supplemental Material F.) LDA, DTs, and SVMs behave in very different ways in both mathematical and procedural terms, yet

may be viewed as complementary to one another in practice (e.g., Curram & Mingers, 1994). Therefore, we employed these procedures separately to look for convergence. Just as language variables can lack predictive strength in isolation, so too are complementary classification methods able to provide better information when considered together rather than separately (e.g., Somers, 1998). For all analyses, we used Fisher's (1936) classical LDA (with equal prior probabilities assigned), the J48 DT algorithm (known for its power and relative simplicity), and the sequential minimal optimization (SMO) SVM (Witten, Frank, & Hall, 2011) to infer the authorship probabilities in *Double Falsehood*.

Results

Whole-play analyses

All plays in our corpus were quantified with the five previously described types of measures. They were then classified, by author, using LDAs, J48 DTs, and SMO SVMs. Finally, *Double Falsehood* was then allowed to be freely classified and assigned to any one of the three authors (Shakespeare, Fletcher, and Theobald) by these three analytic strategies.

The main results of the whole-play analyses are presented in Table 1. Primary statistical reports and cross-validation details are presented in Supplemental Material G.

Function-word results. All three models designated Shakespeare as the best authorial candidate for *Double Falsehood* when considering the eight general function-word classes. Generally speaking, the LDA and SMO SVM approaches were able to discriminate among the authors using vectors comprising all eight classes of function words (see Fig. 1a for the LDA results). Theobald was distinguishable primarily by his high use of prepositions and articles and low use of other stylistic categories of language, whereas Fletcher was quite the opposite. Shakespeare was able to be differentiated as exhibiting a

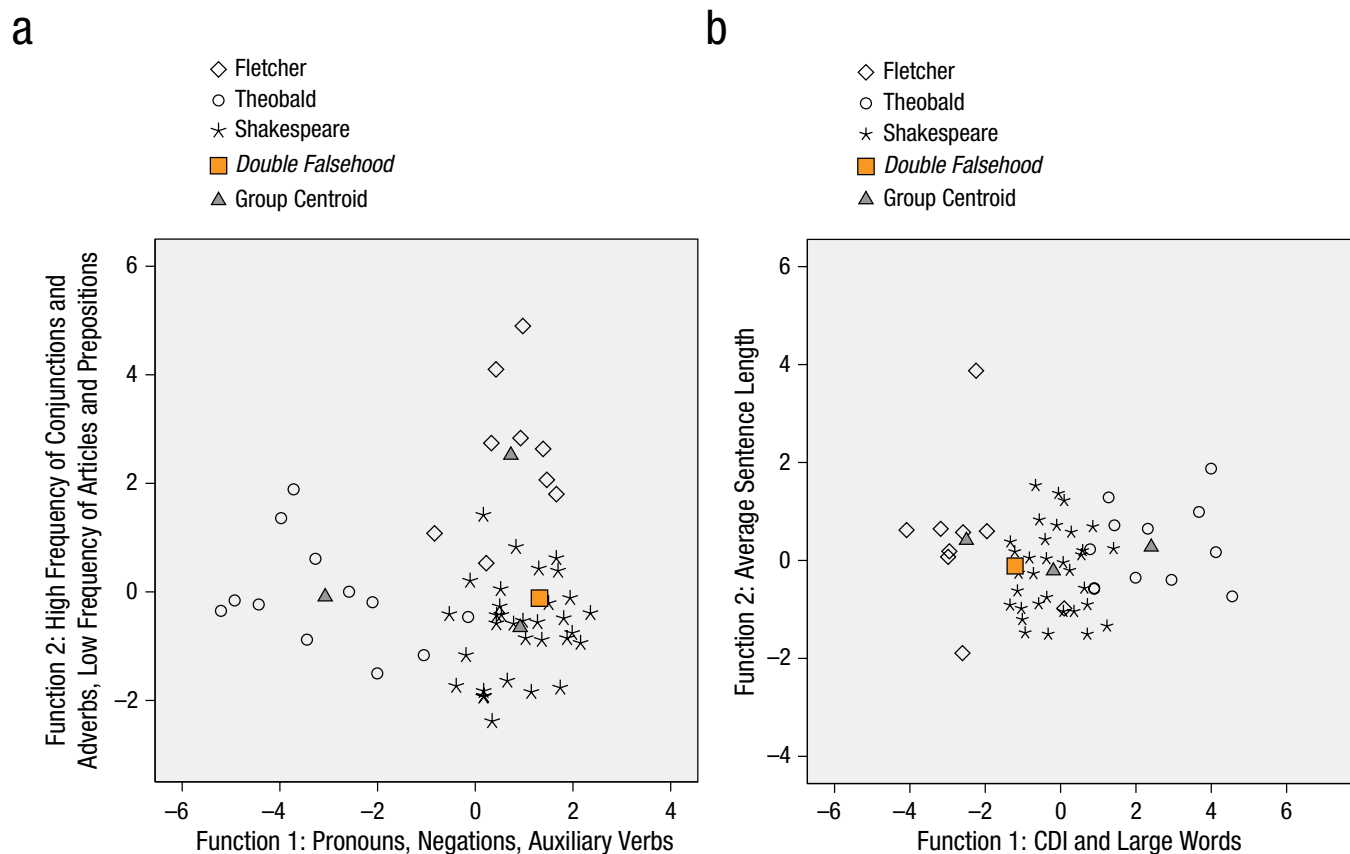


Fig. 1. Results for the linear discriminant analyses using (a) the eight classes of function words and (b) cognitive and stylistic complexity measures. The graphs plot the locations of individual plays and the group centroids for Fletcher, Theobald, and Shakespeare using the functions the models relied on to discriminate among the authors. CDI = categorical-dynamic index.

stylistic trend toward Fletcher that was moderate enough to be distinct. The J48 DT came to the same conclusion (i.e., that Fletcher's style was characterized by a relatively high frequency of "dynamic" function words, such as auxiliary verbs and adverbs), but required fewer function-word classes to successfully discriminate among the authors. These results show that, indeed, all three authors had distinct stylistic psychological signatures along function-word dimensions, and that *Double Falsehood*'s stylistic composition is, on the whole, most analogous to that of Shakespeare.

Results for CDI and complexity. As was the case with the eight classes of function words, all three models assigned *Double Falsehood* to Shakespeare with a high probability, and analyses found that the three authors had unique degrees of cognitive complexity. Analyses found Theobald to be the most complex as measured by CDI and both conventional complexity measures (average number of words per sentence length and use of large words). At the other end of the spectrum, Fletcher exhibited the most dynamism along the CDI dimension, but was somewhat higher in conventional complexity

than Theobald and Shakespeare. As with the eight classes of function words, Shakespeare was somewhere in the middle along the CDI dimension, but showed a trend toward Fletcher's levels of cognitive complexity (relative to Theobald; see Fig. 1b for the LDA results). The DT found that the CDI was the most robust discriminating metric, and relied only on this measure to distinguish among the three authors. The SVM came to the same conclusions.

Results for LIWC content categories. The LDA, DT, and SMO SVM models were able to successfully discriminate among the authors on the basis of the LIWC content categories that were typical of each author. LDA created two vectors that were largely (but not entirely) composed of two classes of content words: (a) words related to thought processes (i.e., cognitive mechanisms) and social processes and (b) words related to emotion, with the latter category broken down into two subclasses (i.e., positive vs. negative emotions). The DT used similar categories to discriminate the authors, but relied only on the broadest emotion category (labeled "affect") and a specific subtype of cognitive mechanism ("certainty").

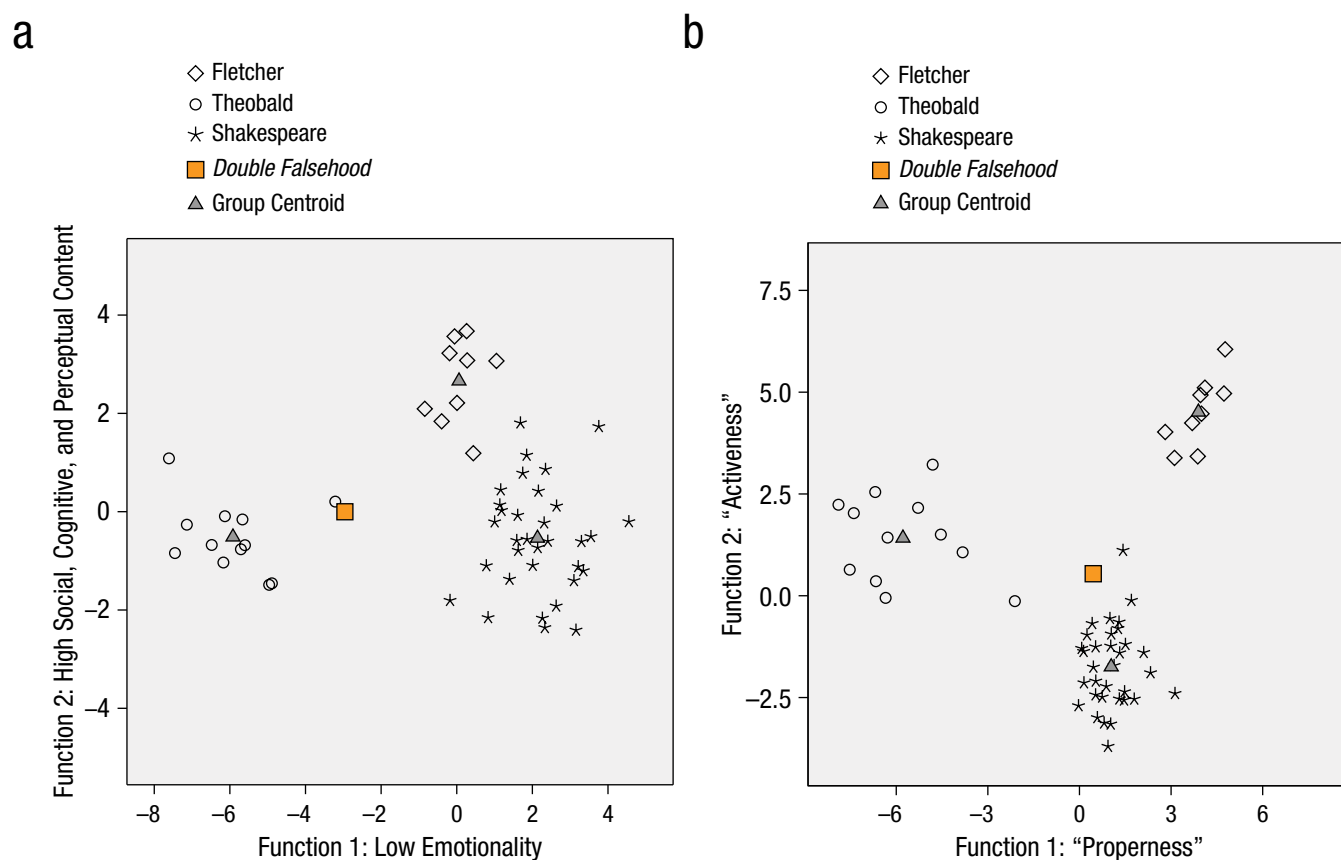


Fig. 2. Results for the linear discriminant analyses using (a) the Linguistic Inquiry and Word Count content categories and (b) the thematic signatures from the meaning extraction method. The graphs plot the locations of individual plays and the group centroids for Fletcher, Theobald, and Shakespeare. In (b), Function 1 ("Properness") is largely (but not entirely) a composite of high use of the "Nobility" and "Femininity" themes and low use of the "Emotionality" and "Romance" themes; Function 2 ("Activeness") is largely a composite of high use of the "Social," "Youth," and "War and Battle" themes and low use of the "Royalty" and "Slumber" themes to a small degree.

Generally speaking, Theobald scored high in overall use of emotion words and lowest in use of cognitive-mechanism words, whereas Fletcher showed a reversal of this pattern. Shakespeare's content exhibited the lowest levels of the emotional vector by far, but scored similarly to Theobald's content on the cognitive-mechanism vector (see Fig. 2a for the LDA results).

In these content analyses, the LDA model disagreed with the DT and SMO SVM models on the most likely authorial candidate. The LDA model indicated that Theobald's content fingerprint was dominant in *Double Falsehood* as a whole, and the latter two models indicated that Shakespeare was the most likely author of this play. Overall, then, there was consensus, but not unanimity, regarding which author's signature was most evident.

MEM results. All three classification procedures were able to discriminate among the authors on the basis of their thematic signatures, using the 13 themes extracted with the MEM. The LDA used two vectors generally composed of (a) high use of the "Nobility" and "Femininity"

themes and low rates of the "Emotionality" and "Romance" themes and (b) high use of the "Social," "Youth," and "War and Battle" themes and low rates of the "Royalty" and "Slumber" themes (see Fig. 2b). Again, the DT required only two of these content categories to distinguish the authors: (a) the "Emotionality" theme (highest for Theobald) and (b) the "Social" theme (highest for Fletcher). The SMO SVM converged with the other procedures in determining that the thematic composition of *Double Falsehood* most closely resembled that of the other works of Shakespeare, with rather high certainty.

Results for low-base-rate words. The LDA, DT, and SMO SVM models were able to distinguish among the three authors using their low-base-rate tell words and phrases with considerable ease; this is expected, as these tells were specifically selected because of their differentiating properties. Generally speaking, all discriminative procedures relied on a similar strategy: classify plays using higher amounts of Shakespeare's trademark phrases and lower amounts of Theobald's trademark phrases and

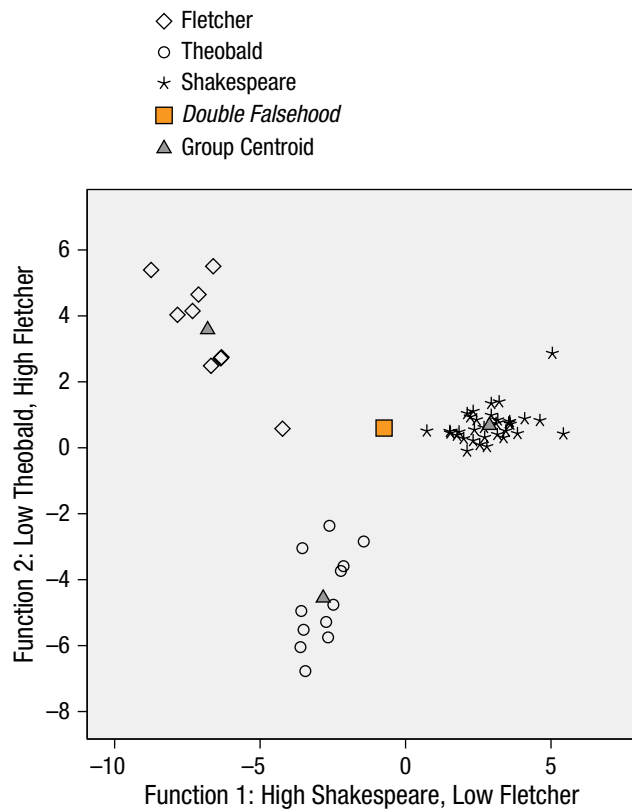


Fig. 3. Results for the linear discriminant analysis of low-base-rate tell words. The graph plots the locations of individual plays and the group centroids for Fletcher, Theobald, and Shakespeare using the functions the model relied on to discriminate among the authors.

then designate the remaining plays as those of Fletcher (see Fig. 3 for the LDA results). Although *Double Falsehood* contained trademark tells that could be reflective of all three authors, all procedures agreed in assigning *Double Falsehood* to Shakespeare with high likelihood, as his low-base-rate words and phrases were the most dominant in the play. Supplemental Material H presents an alternative AID approach to low-base-rate tell words that offers a different, but similar, viewpoint. Supplemental Material I offers a different traditional AID test that relies on distributions of function (rather than content) words.

Analyses by act

Thus far, we have presented results obtained using five types of language measures that quantify psychological phenomena, and three powerful classification techniques, to determine the similarity between each author's psychological signature and that of *Double Falsehood* as whole. Overall, the entire play was consistently linked to Shakespeare with a high probability, which makes it unlikely that it was forged by Theobald. Given that *Cardenio* is generally agreed upon as being the work of both Shakespeare and Fletcher (e.g., Freehafer, 1969;

Kukowski, 1990), one interpretation of our results is that they indeed collaborated in writing this work, which eventually became known as Theobald's *Double Falsehood*, with Fletcher bringing a rather small contribution to the table and Shakespeare playing the role of "master architect." The clearest finding thus far concerns the likely role of Theobald. Although we did not find a total absence of Theobald's signature in *Double Falsehood* as a whole, we simply found very little of it in probabilistic terms, with the exception of one outlying statistic. If the play is a genuine Shakespeare-Fletcher creation, it seems reasonable that any later editing of content may have been made by Theobald himself, as he commonly engaged in such behavior (see Carnegie & Taylor, 2012). This would account for Theobald's strong showing in the LDA model for LIWC content categories. However, we caution against deep interpretation of these findings, as the other two models did not suggest the same contribution.

An important criticism of the research strategy we have presented thus far is that it was relatively broad and crude. That is, the methods were designed to look at *Double Falsehood* as a single entity without regard to its constituent pieces. One of the advantages of using machine-learning procedures is that it is possible to conduct more nuanced analyses. With nuance, however, comes less certainty. From a statistical perspective, there will be more variability, or jitter, inherent to one's findings as one analyzes progressively smaller groups of words. That is, standard word distributions tend to become progressively less reliable as the language samples grow smaller (e.g., Landauer & Dumais, 1997). Nevertheless, each act of *Double Falsehood* was of a sufficient size for us to take a closer look at that level.

To gain a better understanding of the language patterns of *Double Falsehood*, we separated the play into its five constituent acts (after completing the cleaning procedures and whole-play analyses described earlier). Similarly, each comparison play by Theobald, Fletcher, or Shakespeare was automatically segmented into five equal pieces. The resulting sample consisted of 275 observations in total (55 plays \times 5 segments). The comparison plays were segmented so that we could compare the acts of *Double Falsehood* with comparable samples taken from plays, rather than compare each act of *Double Falsehood* with entire plays by the three candidate authors. The words from each act were then submitted to the same language quantification and statistical techniques as were the words in the whole plays.

The data for the individual acts were analyzed using LDA, DT, and SMO SVM procedures analogous to those used for whole plays. The main results of these analyses are presented in Table 2 (primary statistical details are presented in Supplemental Material G). Note that all three analytic approaches were necessarily somewhat more complicated than when we looked at the entire plays.

Table 2. Results for Each Language Measure, by Act and Classification Technique

Classification technique and measure	Act I		Act II		Act III		Act IV		Act V	
	Best candidate	<i>p</i> (%)	Best candidate	<i>p</i> (%)	Best candidate	<i>p</i> (%)	Best candidate	<i>p</i> (%)	Best candidate	<i>p</i> (%)
LDA										
Function-word classes	Shakespeare	95.6	Shakespeare	88.7	Fletcher	54.6	Fletcher	71.4	Fletcher	82.3
CDI, WPS, large words	Shakespeare	66.6	Shakespeare	74.1	Shakespeare	50.8	Fletcher	64.4	Fletcher	63.3
LIWC content categories	Shakespeare	99.8	Theobald	93.2	Shakespeare	99.7	Fletcher	99.4	Shakespeare	71.6
Thematic signatures	Shakespeare	99.7	Shakespeare	96.2	Shakespeare	90.5	Fletcher	72.7	Fletcher	83.1
Low-base-rate tells	Shakespeare	43.5	Shakespeare	50.1	Shakespeare	62.1	Theobald	56.6	Shakespeare	45.7
J48 DT										
Function-word classes	Shakespeare	87.2	Shakespeare	87.2	Shakespeare	54.5	Shakespeare	54.5	Fletcher	96.0
CDI, WPS, large words	Shakespeare	69.3	Shakespeare	69.3	Shakespeare	69.3	Shakespeare	69.3	Fletcher	83.8
LIWC content categories	Shakespeare	93.4	Fletcher	61.9	Shakespeare	93.4	Fletcher	61.9	Fletcher	95.0
Thematic signatures	Shakespeare	92.9	Shakespeare	92.9	Shakespeare	92.9	Shakespeare	92.9	Shakespeare	92.9
Low-base-rate tells	Shakespeare	99.4	Shakespeare	99.4	Theobald	100	Fletcher	87.2	Shakespeare	99.4
SMO SVM										
Function-word classes	Shakespeare	98.5	Shakespeare	97.3	Shakespeare	67.0	Shakespeare	50.6	Fletcher	58.5
CDI, WPS, large words	Shakespeare	81.2	Shakespeare	79.7	Shakespeare	75.6	Shakespeare	57.2	Shakespeare	61.1
LIWC content categories	Shakespeare	95.2	Theobald	99.6	Shakespeare	96.3	Fletcher	97.3	Fletcher	69.7
Thematic signatures	Shakespeare	93.5	Shakespeare	68.7	Shakespeare	93.4	Fletcher	83.5	Fletcher	83.5
Low-base-rate tells	Shakespeare	88.4	Shakespeare	97.4	Theobald	45.2	Fletcher	38.9	Shakespeare	99.6

Note: The probabilities listed in the table are best-candidate probabilities for the linear discriminant analyses (LDAs) and prediction margins for the J48 decision trees (DTs) and sequential minimal optimization support vector machines (SMO SVMs). CDI = categorical-dynamic index; LIWC = Linguistic Inquiry and Word Count; WPS = words per sentence.

This is because the larger number of comparison observations resulted in greater variability, prompting a need to use a greater number of language dimensions in order to classify the samples precisely. Nevertheless, the combinations of psychological language metrics that most models relied on to differentiate the authors were highly similar to (and sometimes exactly the same as) those relied on by the whole-play models. Results generally showed a strong presence of Shakespeare's signature in the early parts of *Double Falsehood*; apparent contributions from Fletcher were greatest in the final two acts. Theobald's signature had only a small presence, in the models of content words and low-base-rate tell words. (See Supplemental Material J for additional discussion and graphic presentation of the results for all by-act analyses.)

Discussion

Was *Double Falsehood* written by Shakespeare and Fletcher, or is it a well-executed forgery by a man who was knowledgeable in both theater practice and Shakespeare's many works? Across analyses of style, content, and low-base-rate words, we found a consistent psychological signature that is consistent with the writings of Shakespeare and Fletcher. Moreover, the by-act results for *Double Falsehood* overlap with much of the general scholarly consensus: As have other researchers, we found a markedly Fletcherian trend in the final acts of the play (Folkenflik, 2012). Additionally, work by other scholars has suggested that there are hints of separate stylistic and content contributions of Shakespeare and Fletcher across all five acts of the play, as did our analyses (cf. Stern, 2011).

Notable is the general absence of Theobald's psychological signature. However, it did make passing statistical appearances in analyses of content words, which are substantially more subject to intentional modification than are function words. Note that Theobald is well known not only for *Double Falsehood* but for his heavy editorial hand as well, so it is unlikely that he would have left *Cardenio* wholly unaltered in the process of crafting it into *Double Falsehood* (Carnegie & Taylor, 2012). Nevertheless, our results offer consistent evidence against the notion that *Double Falsehood* is Theobald's whole-cloth forgery.

Psychological signatures and convergence with historical reports

A promising aspect of our analyses is that the methods allowed for the inference of Shakespeare's, Fletcher's, and Theobald's unique psychological signatures. Recall that function and content words offer different types of psychological information. With regard to both of these broader categories of language, the analyses were able to identify unique thinking styles and thought contents for all three authors. Although the content of thought may be

mimicked in a document with some accuracy, psychological dimensions revealed by function words are nearly impossible to forge without computer assistance. We offer here an analysis of each author's psychological signature; although these conclusions are speculative, we note that our results converge with the general scholarly consensus of the three men's historical profiles, as well as with observers' reports of the authors, their life outcomes, and their recorded behaviors.

Perhaps the strongest contrast can be drawn between Fletcher and Theobald, who consistently showed opposite patterns of language use. Recent studies suggest that people who use language consistent with dynamic thinking tend to be more socially engaged, and to enjoy telling stories more, than people who use these parts of speech at lower rates. In contrast, those who tend to use articles and prepositions at high rates (a pattern consistent with high CDI scores) tend to be organized, logical, and formal in their daily lives (Pennebaker, 2011; Pennebaker & King, 1999).

Recall that Fletcher used more dynamic language than Theobald, who consistently relied on more categorical language. Additionally, Fletcher used relatively high amounts of social LIWC content words and a socially oriented MEM theme. Although few concrete details of Fletcher's life survive (Shakespeare, 1890), it is known that he had many close, long-lasting personal and professional relationships (Ide, 2010), and it was said that he fondly swapped attire with close colleagues (Clark & Aubrey, 1898). There is no evidence that he was particularly scholarly or even particularly organized.

Theobald, on the other hand, left an impressive paper trail suggesting that he was relatively distant and aloof socially, yet meticulous and organized in other areas. Indeed, it is known that he went to great lengths to institute high accuracy in his editorial work (Searly, 1990). Furthermore, Theobald often openly insulted his contemporaries in the process of correcting their mistakes, drawing public recriminations and contempt in the process (e.g., Rogers, 2004).

Most of Shakespeare's personal life is shrouded in mystery, and public records are the basis for most assumptions about his life and livelihood (Potter, 2012). However, Shakespeare's psychological signature suggests that he possessed some similarities to both Fletcher and Theobald. His high use of prepositions, similar to Theobald's, suggests an education focusing on grammar (Tausczik & Pennebaker, 2010). Accordingly, most scholars believe that Shakespeare was classically trained in grammar school during his youth (e.g., Barkan, 2001). With regard to social interests, however, Shakespeare appears to be more similar to Fletcher, as his plays exhibit a relatively dynamic writing style and relatively high use of social content words (see Supplemental Material F). Again, scholars suggest that Shakespeare was socially

focused and interested in climbing higher on the social ladder (see Potter, 2012).

Three important caveats must be considered in interpreting these findings. First, all statistical tests reported here were premised on the belief that only Theobald, Fletcher, and Shakespeare are possible contenders as authors of *Double Falsehood*. If more candidates were considered, the probability estimates for “most likely” author would likely shrink. Second, the analyses were broad and did not examine the plays in a scene-by-scene fashion; finer-grained analyses may better pinpoint specific contributions. Finally, we assumed a fairly informal style of collaboration between Shakespeare and Fletcher. Close collaborations can sometimes result in a writing style that bears weak resemblance to the style of either author. For example, the writing style of Lennon-McCartney songs is different from that of the songs that either man wrote alone (Petrie, Pennebaker, &

Sivertsen, 2008). If *Double Falsehood* was authored by multiple parties, as the current research suggests, it is not entirely clear whether each author’s distinct psychological signature would be discernible, or at what level of granularity (see Supplemental Material Q for further discussion).

Conclusion

In combining the various dimensions of a person’s mental life to create a psychological signature, one is able not only to differentiate that person from others, but also to paint a very rich picture of who that person is, how he or she thinks, and what he or she thinks about. Such techniques show promise for AID, but may be also extremely valuable for enabling multiple disciplines in the psychological sciences to provide better understanding of individuals’ composite mental lives.

Appendix

Table A1. List of Plays Included as Each Author’s Comparison Corpus

Plays by Shakespeare	Plays by Fletcher	Plays by Theobald
<i>A Midsummer Night’s Dream</i>	<i>Bonduca</i>	<i>Decius and Paulina</i>
<i>All’s Well That Ends Well</i>	<i>Rule a Wife, and Have a Wife</i>	<i>Electra</i>
<i>Antony and Cleopatra</i>	<i>The Faithful Shepherdess</i>	<i>Harlequin a Sorcerer</i>
<i>As You Like It</i>	<i>The Humourous Lieutenant</i>	<i>Orestes</i>
<i>Coriolanus</i>	<i>The Loyal Subject</i>	<i>Orpheus and Eurydice</i>
<i>Cymbeline</i>	<i>The Mad Lover</i>	<i>Pan and Syrinx</i>
<i>Hamlet</i>	<i>The Wild Goose Chase</i>	<i>Perseus and Andromeda</i>
<i>Henry IV, Part 1</i>	<i>The Woman’s Prize</i>	<i>The Fatal Secret</i>
<i>Henry IV, Part 2</i>	<i>Wit Without Money</i>	<i>The Happy Captive</i>
<i>Henry V</i>		<i>The Lady’s Triumph</i>
<i>Henry VI, Part 1</i>		<i>The Persian Princess</i>
<i>Henry VI, Part 2</i>		<i>The Rape of Proserpine</i>
<i>Henry VI, Part 3</i>		
<i>Julius Caesar</i>		
<i>King John</i>		
<i>King Lear</i>		
<i>Love’s Labour’s Lost</i>		
<i>Macbeth</i>		
<i>Measure for Measure</i>		
<i>Much Ado About Nothing</i>		
<i>Othello</i>		
<i>Richard II</i>		
<i>Richard III</i>		
<i>Romeo and Juliet</i>		
<i>The Comedy of Errors</i>		
<i>The Merchant of Venice</i>		
<i>The Merry Wives of Windsor</i>		
<i>The Taming of the Shrew</i>		
<i>The Tempest</i>		
<i>The Two Gentlemen of Verona</i>		
<i>The Winter’s Tale</i>		
<i>Troilus and Cressida</i>		
<i>Twelfth Night</i>		

Author Contributions

R. L. Boyd and J. W. Pennebaker both helped to develop the study concept. Both authors contributed to the study design. R. L. Boyd was responsible for nearly all the language quantification, conducted the vast majority of the analyses, and wrote much of the manuscript. J. W. Pennebaker contributed significantly to the body of the manuscript and provided critical revisions. Both authors approved the final version of the manuscript for submission.

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The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at <http://pss.sagepub.com/content/by/supplemental-data>

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