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Tracking Discourse Complexity Preceding Alzheimer's Disease Diagnosis: A Case Study Comparing the Press Conferences of Presidents Ronald Reagan and George Herbert Walker Bush

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Abstract. Changes in some lexical features of language have been associated with the onset and progression of Alzheimer's disease. Here we describe a method to extract key features from discourse transcripts, which we evaluated on non-scripted news conferences from President Ronald Reagan, who was diagnosed with Alzheimer's disease in 1994, and President George Herbert Walker Bush, who has no known diagnosis of Alzheimer's disease. Key word counts previously associated with cognitive decline in Alzheimer's disease were extracted and regression analyses were conducted. President Reagan showed a significant reduction in the number of unique words over time and a significant increase in conversational fillers and non-specific nouns over time. There was no significant trend in these features for President Bush.

Keywords: Early diagnosis, language, medical informatics, natural language processing

INTRODUCTION

Alzheimer's disease (AD) onset can span a decade or more, in which mild cognitive decline precedes more pronounced clinical presentation [1–3]. The appearance of a more precipitous decline is likely the result of failing compensatory strategies, wherein one is eventually unable to mask the underlying deficit [4]. Spontaneous discourse, such as a non-scripted question/answer session, is one such task that puts pressure on the cognitive-linguistic system since it requires immediate formulations of carefully structured responses. In the context of neurological disease, compensatory strategies include reliance on highly over-learned/over-practiced phrases and lexical choices [5–7], with a reliance on non-specific indefinite nouns (e.g., something, anything, etc.) and high-frequency low-imageability[1] verbs (e.g., get, give, go, have, etc.) [10]. In fact, studies comparing the speech of dementia patients and that of healthy aging adults have reported that the linguistic features affected by dementia typically include reduction of available vocabulary [8, 9], reductions in word specificity (increases in indefinite nouns and low-imageability verbs) [9, 10], and lexical repetition [5–7].

President Ronald Reagan (RR) was diagnosed with AD in 1994, six years after he left office; however, speculation of his cognitive decline while in office has been the subject of both academic scholarship and

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[1]The imageability of a term is defined by the ease with which that term gives rise to a sensory mental image—see [18] for details.

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popular debate [11]. The availability of official archives of presidential transcripts offers an opportunity to address questions regarding linguistic changes over time as a bellwether for AD. In the present report, we investigate the claims of RR's cognitive decline through statistical analysis of the transcripts of the President's press conferences. Presidential press conferences typically consist of two parts: 1) a prepared statement read by the president and 2) a spontaneous question/answer session where members of the media can ask questions. It is often the case that the prepared statements are at least partially written by presidential speechwriters or staff members. As a result, for our analysis we focused only on the latter since the nonscripted nature of the discourse is cognitively more taxing.

Our approach is motivated by the foundational work of Snowdon et al. and their "Nun Study" [3]. In this study, researchers analyzed the idea density and grammatical complexity in autobiographical essays written by nuns upon their entry into the convent. The study identified more sophisticated lexical expression in nuns who maintained cognitive health later in life than their peers. To automate the analysis, we adopted a paradigm similar to that proposed by Le et al. [12], where the authors identify longitudinal changes in the novels of writers thought to have suffered from AD, including a significant decrease in the number of unique words in the text, an increase in lexical redundancy, and a decrease in word specificity. Here, we report on similar changes in RR's press conferences and compare these trends against those of President George H.W. Bush (GHWB).

METHODS

Using 46 transcripts of RR's press conferences (1981–1988), we analyzed the lexical features shown to change longitudinally with dementia [3, 12]. For a fixed word corpus, we counted the number of unique words, nonspecific (NS) nouns and fillers, and low-imageability (LI) verbs. Imageability is characterized by the ease with which a term gives rise to a sensory mental image; we used the 14 LI verbs identified by Bird et al. that are common in patients with semantic dementia [10, 18]. We compared the trends we saw in the transcripts of RR with 101 transcripts of the press conferences of GHWB (1989–1993), who has no known diagnosis of AD. We used the press conference transcripts in the American Presidency Project (APP) archive as a data source for this project [13]. The APP is a comprehensive and organized searchable database of presidential documents, including transcripts of speeches, transcripts of news conferences, and other public documents.

Pre-processing

To generate the corpus for analysis, we downloaded each transcript and omitted the prepared statement by the president and all questions/statements by other individuals. We filtered all annotations in brackets. Annotations refer to addendums to the transcripts by the editors to provide context (e.g., [Laughter]). Only answers to specific questions remained. It is known that lexical statistics are dependent on the length of the analyzed document [12]. As a result, to control for the length of the transcripts, we restricted our analysis to the length of the shortest record in the RR set: 1,400 words. As such, we focused on the first 1,400 words of each document. For RR, this included the complete set of news conferences (46 of 46). For GHWB, this included 101 of the available 137 news conferences, as these are the only ones that met the threshold of 1,400 words.

Text statistics

We calculated the following statistics for each transcript using the Natural Language Processing Tool Kit in Python (NLTK) [14]:

Number of unique words: The raw text from the presidents' responses was split into individual words. We changed the words to lowercase and stemmed them. Stemming refers to reducing each word to their stem, base, or root form. For example, the words *argument* and *arguments* share a common root form*, argument.* We automate this process using the Lancaster Stemmer in NLTK [14]. A histogram of the resulting root words was generated, and the unique word count was readily available. Note that in the example above, *argument* and *arguments* are treated as the same word since they share a common root. For both presidents, we removed six transcripts that fell more than two standard deviations from the mean: one transcript from RR's data; five, from GHWB's data.

Estimation of number of filler words, NS nouns, and LI verbs: As with the unique word count, the transcripts were split into individual words and then stemmed. For each of the three categories, we counted the number of occurrences of the following words in the transcript: Fillers: "*well*", "*so*", "*basically*", "*actually*", "*literally*", "*um*", "*ah*" [12]; NS nouns: any pronoun or

noun that contains "*thing*" (e.g. something, anything); LI verbs: The 14 LI verbs observed in patients with semantic dementia [10].

There was a large difference in the average frequency between the LI verbs and the other two categories. As a result, we separated the LI verbs into their own category. For the NS and fillers, we removed six transcripts that fell more than two standard deviations from the mean: two transcripts from RR's data; four, from GHWB's data. For LI verbs, we removed four transcripts that fell more than 2 standard deviations from the mean: one from RR's data; three from GHWB's data.

As have other researchers who have analyzed lexical trends in individuals with suspected AD [3, 12], we analyzed temporal trends in the linguistic markers described above. For each linguistic feature, we carried out regression analysis to evaluate statistically significant changes in these variables over time. We performed this analysis for both RR and GHWB.

RESULTS

At the start of their presidencies, RR was 69 years old and GHWB was 64 years old. Table 1 (top) contains a list of descriptive statistics for the analyzed press conferences. There is a significant difference in the number of press conferences per year between the two presidents (unpaired $t = 31.3$, $p < 0.0001$); in fact, RR participated in far fewer press conferences than any other president since 1929, with 56% of these occurring in his first term and 85% occurring in his first 6 years in office [13]. On average, GHWB used fewer unique words than RR (unpaired $t = 2.6$, $p = 0.010$); more LI verbs than RR (unpaired $t = 7.8$, $p < 0.0001$); and fewer NS nouns and fillers (unpaired $t = 3.9$, $p = 0.0001$). Differences in these statistics are indicative of individual differences in linguistic abilities or speaking style; as in [12], our interest is in comparing longitudinal changes in these statistics rather than comparing their absolute values.

In Table 1 (bottom), we show the Pearson correlation coefficient between the transcript index number and the dependent variables. For RR, there is a significant decrease in the number of unique words over time ($R = -0.446$, $p = 0.002$). In contrast, GHWB exhibits a slightly negative, but statistically insignificant trend along this linguistic dimension. Similarly, we also evaluated changes in the frequency of NS nouns and fillers over time. For RR, there is a significant increase in this variable ($R = 0.358$, $p = 0.017$), whereas GHWB does not exhibit any significant change. In Fig. 1, we plotted the individual data points and the corresponding trend lines for RR for the two statistically significant variables in Table 1. The number of LI verbs does not exhibit statistically significant temporal trends for either president.

Table 1
Descriptive statistics (mean and standard deviations) of President Ronald Reagan's and President George H.W. Bush's news conferences (top) and linear regression analysis between the dependent variables and the transcript index (bottom). Transcript index refers to the order in which the press conferences occurred from first to last

	Ronald Reagan *Mean (S.D.)*		George H.W. Bush *Mean (S.D.)*	
Conferences per Year	5.8 (1.7)		34.5 (6.1)	
Unique Words	413.6 (17.2)		405.4 (17.6)	
Non-specific Nouns+Fillers	25.1 (6.3)		21.5 (4.3)	
Low-imageability Verbs	94.6 (10.0)		110.5 (11.9)	
	Coeff.	*p*-value	*Coeff.*	*p*-value
Unique Words	**–0.446**	**0.002**	–0.098	0.343
Non-specific Nouns+Fillers	**0.358**	**0.017**	0.053	0.608
Low-imageability Verbs	0.032	0.835	–0.099	0.333

The bold values highlight the variables that are statistically significant.

In an effort to more closely match for age, we repeated the comparative analysis above using all of RR's press conferences and only the last 46 press conferences for GHWB (to match RR's number of conferences). At the start of the new analysis GHWB was 66 years old. For RR the statistics do not change since the data are the same. For GHWB, there is still no significant change in the number of unique words over time ($R = 0.018$, $p = 0.369$), in the number of NS nouns and fillers ($R = 0.046$, $p = 0.150$), and in the number of LI verbs ($R = 0.0195$, $p = 0.354$).

DISCUSSION

President Reagan was not diagnosed with AD until August of 1994, but the results of our analyses suggest that changes in speaking patterns were becoming detectable years prior to clinical diagnosis. Analysis of his transcripts revealed significant differences in variables known to be associated with the onset of dementia. We found that the use of unique words in the discourse of RR declined over time, and the use of non-specific nouns and fillers increased over time. To address the potential confound associated with changes resulting from healthy aging, we compare RR's transcripts to those of GHWB. At the start of their presidencies, RR was 69 years old, and GHWB was 64

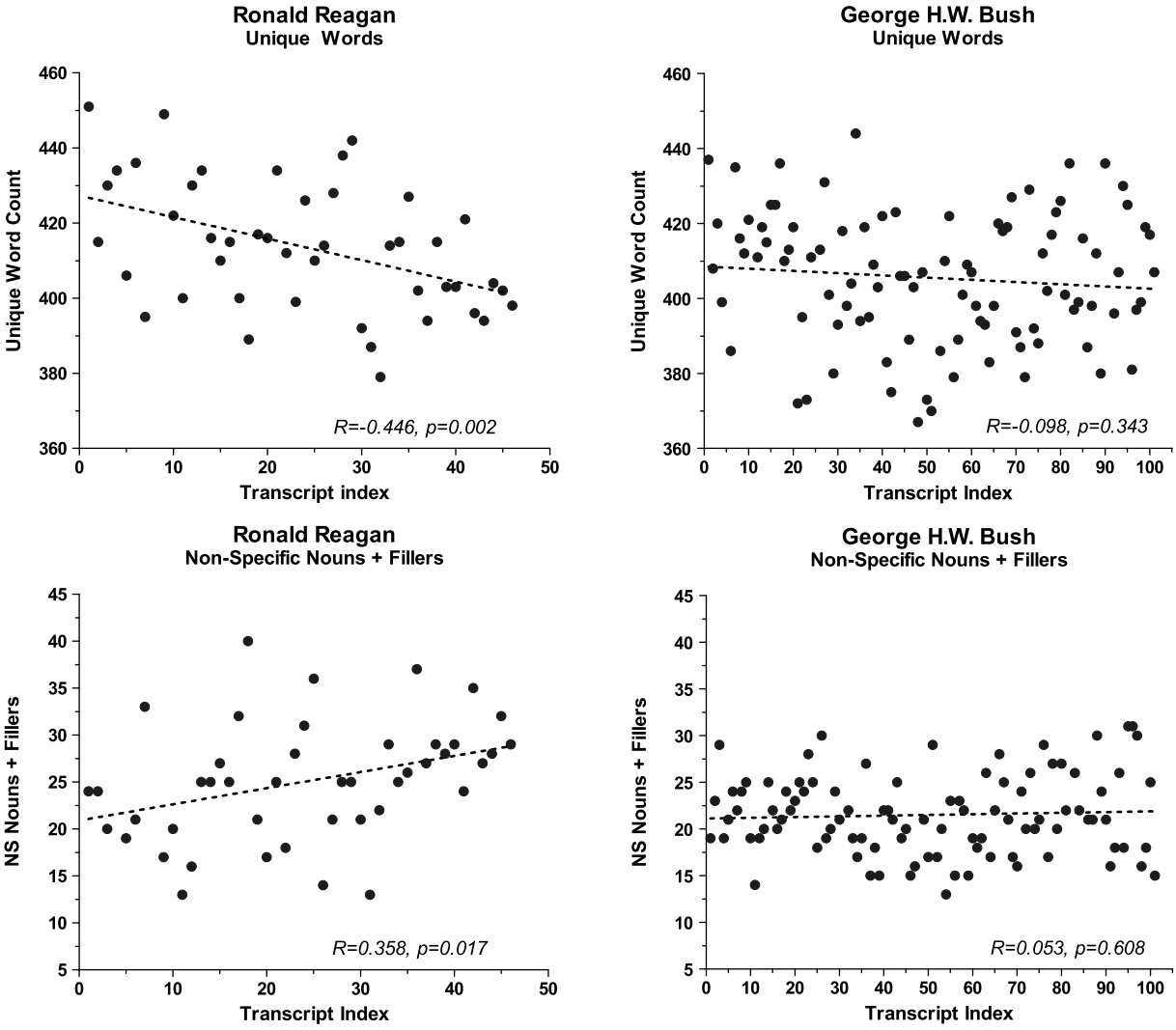

Fig. 1. Linear regression analysis of lexical variables that have been linked to dementia and Alzheimer's disease for President Ronald Reagan and President George H.W. Bush. Transcript index refers to the order in which the press conferences occurred from first to last.

(the years 1981 and 1989 respectively). Although the two age spans differ slightly, GHWB provides the most comparable case among modern American presidents. Furthermore, when we analyze the press conferences from GHWB's last two years in office (starting at age 66), there is still no statistically significant change in these linguistic variables.

These findings are consistent with the literature evaluating linguistic patterns in individuals with dementia, wherein both a decline in the number of unique words and the increased use of NS nouns and lexical fillers have been shown to be correlated with impaired cognitive and linguistic function [3, 5–7, 10, 12]. Unlike other studies [10, 12], changes in NS verbs were not detected. This could be due to the short nature of the transcripts—perhaps a sample of 1400 words is insufficient to detect significant changes in this variable. Furthermore, the findings are consistent with Gottschalk's findings that RR's presidential debates contained indicators of dementia as early as 1980 [11]. The Gottschalk-Gleser diagnostic scale, on which Gottschalk based his conclusions, analyzes verbal behavior as an indicator of impairment. This includes linguistic features, such as failure to complete sentences or phrases, and repetitive speech [16, 17].

Normal age-related decline in variables related to linguistic complexity has been documented in the literature [8, 9, 15, 19]. For example, the meta-analysis in [19] analyzed the effects of healthy aging on vocabulary scores. Relevant to the present paper, the author

analyzed the change in two measures of vocabulary size, the vocabulary subtest of the Wechsler deterioration quotient (WAIS-R) [20] and the Shipley scale [21], as a function of age (Fig. 3 in [19]). The meta-analysis was comprised of 95 studies that used the WAIS-R scale (mean ages 64–76) and 46 studies that used the Shipley scale (mean ages 67–80). The WAIS-R studies showed a slightly negative correlation ($R = -0.22$) with age and the Shipley studies showed no correlation ($R = -0.05$) with age. While it is unclear what the impact of age is on linguistic complexity, the consensus in the literature is that disease-related linguistic ability decline occurs with a greater rate of change when compared to language deficit resulting from healthy aging [8–10]. This is consistent with our comparative analyses showing significant differences in variables known to be associated with the onset of dementia for RR, but not for GHWB.

Le et al. showed that longitudinal statistical analysis of writing samples could presage later-life dementia [12]. Our findings suggest that in addition to textual analyses of writing samples, analysis of extemporaneous spoken language may also be used to identify indicators of dementia. We note that the approach is not specific to cognitive-linguistic changes associated with AD. Many neurological conditions lead to compensatory strategies that can possibly be detected through automated analysis of linguistic variables. As such, the approach outlined here potentially represents a valuable, noninvasive diagnostic tool that may be adaptable to different neurological conditions and a variety of discourse types. One of the limitations of our approach is the large sample size spanning many years required for analysis. Because our goal is to detect small changes in these linguistic variables over time, longitudinal data are required unless these changes are drastic. However this limitation could be addressed by modifying traditional evaluation protocols to include the elicitation of regular discourse samples.

DISCLOSURE STATEMENT

Authors' disclosures available online (http://j-alz.com/manuscript-disclosures/14-2763r2).

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