
Speech Errors in Alzheimer's Disease: Reevaluating Morphosyntactic Preservation

Lori J. P. Altmann
Gerontology Center
University of Kansas
Lawrence

Daniel Kempler
Schools of Medicine and
Gerontology
University of
Southern California
Los Angeles

Elaine S. Andersen
Department of Linguistics and Program in
Neuroscience
University of
Southern California
Los Angeles

Researchers studying the speech of individuals with probable Alzheimer's disease (PAD) report that morphosyntax is preserved relative to lexical aspects of speech. The current study questions whether dividing all errors into only two categories, morphosyntactic and lexical, is warranted, given the theoretical controversies concerning the production and representation of pronouns and closed-class words in particular. Two experiments compare the speech output of 10 individuals with Alzheimer's disease to that of 15 healthy age- and education-matched speakers. Results of the first experiment indicate that the pattern of errors in the speech of participants with mild PAD reflects an across-the-board increase in the same types of errors made by healthy older speakers, including closed-class and morphosyntactic errors. In the second task, participants produced a grammatical sentence from written stimuli consisting of a transitive verb and two nouns. Only adults with Alzheimer's disease had difficulties with this task, producing many more closed-class word errors than did healthy older adults. Three of the participants with PAD produced nearly agrammatic speech in this task. These 3 people did not differ from the rest of the PAD group in age, education, working memory, or degree of semantic impairment. Further, error rates on the two tasks were highly correlated. We conclude that morphosyntax is not preserved in the speech output of individuals with PAD, but is vulnerable to errors along with all aspects of language that must be generated by the speaker. We suggest that these results best support a model of speech production in which all words are represented by semantic and grammatical features, both of which are vulnerable to failures of activation when there is damage or noise in the system as a result of pathology, trauma, or even divided attention.

KEY WORDS: Alzheimer's disease, speech production, semantic impairment, function words, morphosyntax

In the most common description of speech production in probable Alzheimer's disease (PAD), speech output is characterized by a semantic impairment that leads to impairments in the use of open-class content elements of speech, such as nouns, verbs, and adjectives (Albert & Milberg, 1989; Bayles, 1982; Chertkow & Bub, 1990; Hier, Hagenlocker, & Shindler, 1985; Kempler, 1991; Kempler & Zelinski, 1994; Nicholas, Obler, Albert, & Helm-Estabrooks, 1985). In contrast, other aspects of language are typically described as preserved, especially morphosyntax, which includes grammatical inflections, syntactic processes, and closed-class words such as determiners, auxiliary verbs, modals, and prepositions (Bayles, 1982; Kempler, Curtiss, & Jackson, 1987; Kirschner, 1982; Patel & Satz, 1994; Schwartz, Marin, & Saffran, 1979). This portrait of the speech of individuals with PAD is often

interpreted as support for a modular view of language in which open-class word production (and perhaps pronouns, see below) is impaired by semantic deficits caused by the disease, whereas the use of grammatical elements is characterized as being relatively normal. However, other researchers have reported that, even at early stages of the disease, individuals with PAD show disturbances in morphosyntax (Altmann, Andersen, & Kempler, 1993; Courtney, Frank, & O'Day, 1999; Obler, 1983). This paper addresses these apparently contradictory reports by examining the frequency of errors of lexical choice and morphosyntax by speakers with PAD and healthy older people. To accomplish this, we suggest a schema for categorizing these errors that avoids some of the ambiguities in earlier studies. This schema provides a format that allows the testing of these findings against three well-known theories of speech production, those of Garrett (1975, 1982), of Levelt (1989), and of Bates and colleagues (e.g., Bates & Wulfeck, 1989). To foreshadow our results, the pattern of errors in the speech of individuals with mild PAD reflects an across-the-board increase in the same types of errors that healthy older speakers make in everyday speech, including increases in both morphosyntactic and closed-class word errors. In contrast, errors in a constrained speech task that requires participants to provide the necessary closed-class words to form a grammatical sentence occurred primarily on closed-class words. These results suggest that speakers with PAD produce errors in any aspects of speech that they are required to generate themselves. This pattern is interpreted within an interactive model in which words are represented by patterns of activation across both semantic and grammatical features.

Researchers disagree as to whether the language difficulties of individuals with PAD are actually caused by semantic impairment. Some researchers have found near-normal performance on online tasks, such as semantic priming, and thus conclude that semantic representations are intact in Alzheimer's disease, but that controlled, conscious access to these representations is impaired (Nebes, 1989; Nebes & Brady, 1988; Ober & Shenaut, 1995; Ober, Shenaut, & Reed, 1995; Shenaut & Ober, 1996). These researchers frequently attribute semantic errors in speech and picture naming to attentional deficits, although they rarely include a measure of attention in their studies. Other researchers assert that although access to semantic knowledge may be a problem, the primary deficit is the degradation of semantic knowledge (Bayles, 1982; Bayles, Tomoeda, & Cruz, 1999; Chertkow & Bub, 1990; Henderson, Mack, Freed, Kempler, & Andersen, 1990; Hier et al., 1985; Martin & Fedio, 1983; Nicholas et al., 1985). Two recent studies suggest a way to reconcile these opposing views by specifying that word knowledge is impaired at the

property or featural level, with higher-frequency information being the most resilient to damage. Smith, Faust, Beeman, Kennedy, and Perry (1995) examine the semantic knowledge of individuals with PAD using timed knowledge probes (e.g., "True or false: An apple is red"). They find that the participants with PAD respond similarly to control participants on items with high prototypicality but are less accurate and slower to verify distinctive features of low-typicality items. For example, in the category *trees*, responses to questions about characteristics of *oak* are faster and more accurate than to questions about *palm*. Smith et al. suggest that Alzheimer's disease degrades low-frequency, property-level information about objects; consequently, speakers have difficulty with tasks that require the full semantic activation of words, such as picture naming or producing the name of an item when given its definition. Further, since loss of low-frequency information does not affect the overall organization of semantic fields, individuals with PAD perform normally on tasks that test semantic organization but do not necessarily require complete semantic activation, such as semantic priming and item categorization. Approaching similar issues from a different direction, Kempler and colleagues examined online and offline grammatical ability in individuals with PAD and healthy older adults (Kempler, Almor, MacDonald, & Andersen, 2000; Kempler, Almor, Tyler, Andersen, & MacDonald, 1998). They find the two groups show similar sensitivity to grammatical violations in online tasks when encountering subject-verb agreement errors or violations of transitivity (i.e., the presence of a postverbal preposition following a transitive verb or the absence of a required preposition following an intransitive verb). In contrast, on offline tests of grammatical awareness such as grammaticality judgments or sentence-picture matching, participants with PAD are significantly impaired. Kempler et al. hypothesize that individuals with PAD succeed at online tasks that can be accomplished by activating only the most frequent information associated with words (which includes, for example, grammatical class, number, person, and animacy) but show impairments when tasks require full activation and integration of the semantic material in a sentence. Thus, both Smith et al. and Kempler et al. attribute the patterns in their data to good performance when only high-frequency information is necessary and impaired performance when the task requires the full activation of both high- and lower-frequency linguistic material. This integrative approach to language difficulties in Alzheimer's disease can account for the findings of intact performance on tasks such as semantic priming that require activation of only the most frequent semantic features while also explaining the difficulty experienced in tasks that require more complete semantic activation, such as picture naming and

sentence-picture matching. Based on this model, we believe that semantics are impaired in this population and that the different results on online versus offline tasks should be attributed to task demands.

Issues in Error Categorization

Kempler et al. (1987) report many lexical errors and very few morphosyntactic errors in the spontaneous speech of individuals with PAD. They attribute the lexical errors they find to semantic impairment and the breakdown of controlled processing in lexical choice, whereas the lack of morphosyntactic errors is attributed to the preservation of relatively automatic, predictable, high-frequency operations such as those in grammatical processing. Despite the explanation the authors offer in terms of relative automaticity of lexical and grammatical processing, this study has been cited as evidence of a dissociation between lexical and grammatical processing and as support for a modular theory of language (e.g., Caplan & Waters, 1999; Keller & Rech, 1998; Nebes, 1989, 1992; Schwartz & Chawluk, 1990). To clarify the original findings in Kempler et al. (1987), the current study examines the spontaneous speech of people with PAD, incorporating certain methodological changes to accommodate contemporary psycholinguistic theories about lexical and morphosyntactic representation. The most important change affects the categorization of errors. For example, Kempler et al. (1987) classify the following errors as morphosyntactic: constituent structure errors (missing matrix or subordinate clauses, missing subjects or predicates), agreement errors (wrong or missing noun or verb morphology), erroneous use of “nonlexical¹ grammatical markers,” and constituent movement (aberrant word order). Few linguists or psycholinguists would argue against including constituent structure errors, anomalous word order, and agreement errors in the category of morphosyntactic errors. However, the inclusion of errors in the use of nonlexical grammatical markers (i.e., closed-class word substitutions) in this category is not universally accepted due to theoretical questions regarding the appropriate description of closed-class words. The three psycholinguistic theories of speech production discussed below vary considerably in this regard.

Garrett's theory, the most traditional approach to speech production, is based on a modular approach to language representation. This view specifies that open- and closed-class words are accessed by different processors: one processor, dedicated to lexical semantics, accesses open-class words, and the other processor

accesses sentence structures, grammatical inflections, and closed-class words (Garrett, 1980, 1984). In this theory, closed-class words and other grammatical morphemes are not independent entities at all, but are syntactic entities accessed as part of a sentence frame. Working within this model, any closed-class word error in speech is attributable to syntactic deficits, and word omissions are labeled as syntactic errors involving the sentence frame (Biassou, Obler, Nespoulous, Dordain, & Harris, 1997; Bradley & Garrett, 1983; Garrett, 1982). Consequently, the speech of individuals with PAD with semantic deficits alongside intact syntactic processing should reveal normal operation of the syntactic processor with few if any errors affecting morphosyntax or closed-class words.

In contrast, Levelt's theory distinguishes between closed-class words with semantic content, such as modals and locational prepositions, and purely grammatical closed-class words like auxiliaries and determiners (Levelt, 1989). In this theory, semantically represented closed-class words are accessed directly by message level (nonlinguistic, conceptual) information just as open-class words are, but grammatical closed-class words are accessed by syntactic building procedures triggered by the previous activation of the syntactic portions of open-class lemmas.² Thus, according to this theory, speakers with semantic deficits and no syntactic impairment should make errors only on open-class words and semantically represented closed-class words, but should not err on purely grammatical closed-class words such as auxiliaries and determiners.

A third group of theorists suggests that closed-class words have semantic representations, but these have relatively few features compared to open-class words, and so might be vulnerable when there is a semantic impairment (Allen & Seidenberg, 1999; Bates & Wulfeck, 1989; Goodglass & Menn, 1985; Plaut & Shallice, 1993). Based on this theory, individuals with a semantic deficit would be expected to make more errors than healthy speakers on open- and closed-class words. These three speech-production theories make very different predictions about the types of closed-class word errors that might be present in the speech of individuals with PAD; therefore, error patterns of speakers from this population can be used to evaluate these theories of linguistic representation. To facilitate this comparison, closed-class errors form a separate error category that includes all errors on freestanding closed-class items, whereas morphosyntactic errors are limited to errors affecting constituent structure, word order, and grammatical inflections.

¹In some linguistic and psycholinguistic theories, the term “lexical” is only applied to open-class content words. See discussion of Garrett's theory here for an example.

²A lemma is a theoretical representation of a word consisting of four parts representing different aspects of word knowledge: phonology, morphology, syntax, and semantics (see Levelt, 1989, for details.)

Another consideration when tabulating errors is that Kempler et al. (1987) do not systematically include closed-class word omissions in any category. A more recent project finds that the proportion of closed-class word omissions compared to substitutions increases with severity of impairment in Alzheimer's disease (Altmann et al., 1995). Considering that the severity of participants with PAD in Kempler et al. (1987) varies from relatively mild to severe (Mini-Mental Status Examination (MMSE) = 2–26), there are likely a large number of closed-class omissions in their narratives that are not systematically included in a particular category. For these reasons, the current study tabulates both substitutions and omissions of closed-class vocabulary. Similarly, the open-class error category also includes both omissions and substitutions.

Pronouns constitute another category of words that is known to cause difficulties for people with PAD (Bates & Goodman, 1997; Ripich & Terrell, 1988). Depending on one's theory, pronouns might be considered either open- or closed-class words. Linguists usually categorize pronouns as closed-class items, since they form a small, exclusive set of words that is not open to lexical innovation (e.g., Finegan, 1989; Yule, 1996). However, pronouns and other deictic words are similar to open-class words in that they have referential meaning in context, although pronoun reference necessarily varies between contexts much more than open-class word meaning. To further complicate matters, the (over-) use of pronouns by individuals with PAD (as well as their poor comprehension of them) has been traced to working memory deficits rather than semantic impairments (Almor, Kempler, MacDonald, Andersen, & Tyler, 1999). Due to the ambiguity of this issue, pronoun and other deictic errors are included here as a separate error category apart from errors on either open- or closed-class words. This varies from the categorization used by Kempler et al. (1987) in that those researchers included pronoun errors with lexical (i.e., open class) errors. In the current study, the category of pronoun errors includes substitutions and omissions of pronouns and unrecoverable reference errors. Thus, we have arrived at four types of speech-production errors to analyze: (1) closed-class word substitutions and omissions, (2) open-class word substitutions and omissions, (3) pronoun errors of all types, and (4) morphosyntactic errors (i.e., incorrect inflections, word order errors, and missing matrix or subordinate clauses).

Experiment 1: Spontaneous Speech

In the first experiment, the distribution and frequency of errors in the spontaneous speech of individuals with PAD and healthy older speakers are compared

in order to determine: (a) whether errors are limited to open-class words and pronouns while morphosyntax and closed-class word use are preserved and (b) whether the distribution of errors supports one of the three speech-production theories discussed above. Based on previous studies (Altmann, 1998; Altmann et al., 1993), we predict individuals with PAD will make more errors than healthy speakers, but there will be no group differences in the distribution of errors across word categories.

Method

Participants

Ten adults diagnosed with probable Alzheimer's disease using NINCDS-ADRDA criteria (McKhann et al., 1984) participated in the study. In addition, 15 healthy elderly (HE) adults were recruited by advertising in alumni newsletters, local newspapers, and senior centers in the Los Angeles area. All participants were native speakers of Standard English, had vision and hearing adequate to perform the task, and had no history of stroke or other neurological impairment. Means for the Mini-Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975) distinguished the two groups (HE = 29.00 [range 27–30], PAD = 20.45 [*SD* 1.4, range 18–22]; $t(23) = 17.596, p < .0001$). However, the groups did not differ significantly in age (HE = 76.44 years, PAD = 80.40 years; $t(23) = 1.419, p > .15$) or years of education (HE = 15.7 years, PAD = 15.0 years; $t(23) = .756, p > .40$).

Procedure

All participants with PAD were tested at their homes or day-care facilities over five sessions, each lasting less than 90 minutes. Each session contained a speech-production task, various tests of cognitive and semantic impairment, and other tasks unrelated to the current study. HE individuals completed the speech production, cognitive, and semantic tasks in one test session. All production tasks were audiotaped, transcribed verbatim by a trained researcher, and checked for accuracy by the first author. All real words (i.e., excluding fillers like *um* and *ah*) produced by the speaker were counted, including self-corrections and carrier phrases, which together constituted less than 5% of the corpora.

The four types of errors defined above, shown in Table 1, were tabulated once by the first author and again by a trained graduate student. Only uncorrected errors were included. Disagreements in error counts and categorization were resolved by discussion; when agreement could not be reached, the error was excluded from further analysis (1% of errors). The error identification and classification parameters proved highly reliable between scorers ($r = .92$).

Table 1. Error types found in the speech of participants with PAD.

Error type	Error subtype	Example
Closed class	Substitution	There was one thing <i>what</i> I was interested in...
	Omission	You know, back then in the '20s you didn't have much __ anything except just go __ the doctor
Open class	Substitution	I've never taken one of their lessons. I'm too much <i>fear</i> and all that.
	Omission	I have one full blooded sister, and we're still very close. And what __ it even moreso is that she's married to my husband's brother.
Morphosyntax	Inflectional	It was a pecan <i>trees</i> .
	Inflectional	I believe some, or if not many or most, of my memories <i>has, seems</i> to be improving.
Pronoun	Substitution	It doesn't go blank on me as often as <i>I</i> used to.
	Omission	Lisa had thrown the plate and broken __. (missing <i>it</i>)

Materials

The speech data were drawn from conversation with the researcher about familiar topics: the participants' career, family life, and hobbies. Since content was not an issue in this study, discussion was allowed to range freely to include topics the participant preferred. Analyzed speech samples terminated at the end of the conversational turn in which 500 words of participants' speech was reached. The initial interviews of two participants with PAD did not provide enough material, and a portion of a later conversation was included. The mean length of the narratives of the group with PAD was 471 words (range 196–555 words). Narratives of the HE adults averaged 488 words (range 286–547 words). The error frequency was converted to the number of errors per hundred words to control for individual differences in verbosity.

Two verbal working memory and three semantic measures were also administered to participants. The first working memory task was digit span backward (Wechsler, 1987); the HE group scored significantly higher on this measure than did the PAD group (HE $M = 5.7$ [range 3–7], PAD $M = 4.0$ [range 2–7]; $t(23) = 2.837$, $p < .01$). The second working memory task consisted of a two-part ordering task, which has been shown elsewhere to correlate highly with other types of

linguistic and working memory performance (Almor et al., 1999; Almor, Kempler, MacDonald, & Andersen, 1997; Kempler et al., 1998). In this task, participants heard lists of digits or months and were required to put them into canonical order. The first level of the test used two-item lists; if participants met criterion on this level (i.e., three out of four lists recalled and ordered correctly), they were tested at the next higher level. The largest sets of stimuli tested contained six items to be ordered. Reported scores represent the percentage of correct trials out of the possible 40 items. Scores on this task were also higher for the HE group ($M = 77%$, range 55–90%) than for the PAD group ($M = 35%$, range 10–63%; $t(23) = 6.616$, $p < .0001$). The first semantic measure was the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997), which was given to all participants. Scores on this task are reported as percentage correct of 175 possible trials. Although PPVT scores for the participants with mild PAD were relatively good ($M = 87%$ [$SD 8.7%$], range 68–95%), they were still significantly below those of the age- and education-matched HE group ($M = 97%$ [$SD 2.3$]; $t(23) = 4.131$, $p < .001$). In addition, an untimed picture-naming task was administered only to the PAD group, because healthy older adults are typically at ceiling on such tasks (Kempler & Zelinski, 1994). This 96-item test included 12 items from each of eight semantic categories covering a range of familiarity and prototypicality within each category and was presented using Psyscope on a Mac Classic or similar computer. The response scored was the best response offered. Naming scores varied from 68% to 92% correct. A companion comprehension task was also administered in which participants identified the target item from a 2×2 array that included distractors that were visually, semantically, or visually and semantically related to the target. In addition, the number of semantic paraphasias in naming was computed, because this particular error type is often considered a hallmark of semantic impairment (e.g., Chertkow & Bub, 1990; Hodges, Patterson, Oxbury, & Funnell, 1992; Nicholas, Obler, Au, & Albert, 1996; Nickles, 1997; Parasuranam & Nestor, 1993), whereas other types of response, such as “I don't know” answers, may signal attentional failures (Nicholas et al., 1996). Naming errors considered semantic paraphasias were those in which the name of an item from the same semantic category was substituted for the target (e.g., *horse* for *cow*). The number of semantic paraphasias varied between 1 and 16 and did not perfectly correlate with naming scores. Because there may be a postsemantic working memory component to these semantic measures, correlations were computed between each semantic measure and the two working memory measures. Scores on the comprehension task proved to be collinear with ordering scores ($r^2 = .92$). The naming task also

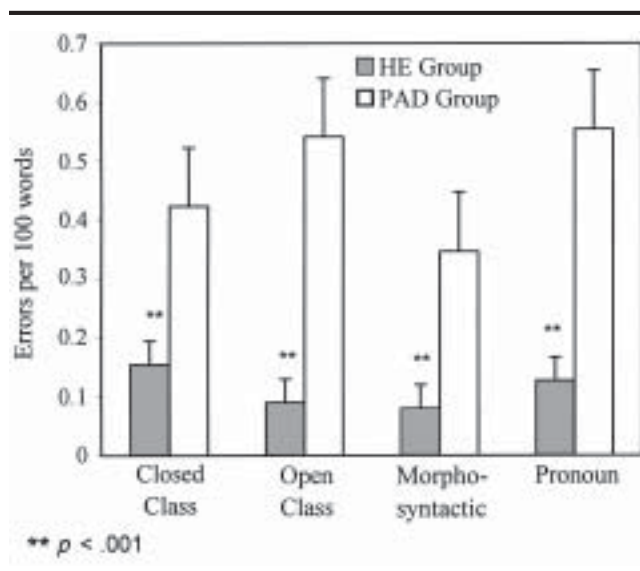
shared significant variance with the ordering measure ($r = .624, p = .05$), but PPVT and the number of semantic paraphasias did not. Consequently, total naming and comprehension score were excluded from further analyses.

Results

The distribution of errors across categories was analyzed using a 2×4 (Group \times Error Category) ANOVA with the number of errors per 100 words as the dependent variable. Figure 1 illustrates that individuals with PAD made more errors in all categories than HE adults. This was reflected in a highly significant main effect of Group [$F(1, 92) = 48.555, p < .0001$]. On the other hand, there was no main effect of Error Category [$F(3, 92) = 1.189, p > .30$] because no particular error type dominated. In addition, the Group \times Error Category interaction failed to reach significance [$F(1, 92) = .980, p > .40$]. This confirmed our prediction that the distribution of the four types of error would not differ between the two groups.

We also examined the distribution of omission and substitution errors across open- and closed-class word categories using a $2 \times 2 \times 2$ (Group \times Error Category \times Error Type) ANOVA. This analysis revealed a significant main effect of Group [$F(1, 96) = 14.899, p < .001$], mirroring the finding above, as well as an Error Type \times Error Category interaction [$F(1, 96) = 6.827, p < .01$]. The nature of this interaction was that both groups tended to omit closed-class words but substitute open-class words. No other effects in this analysis were significant.

Figure 1. Errors per 100 words in spontaneous speech.



To examine the relationship between participants' error rates in spontaneous speech and cognitive variables, a stepwise regression with the F-to-enter set at 3.0 was computed using total errors³ per 100 words as the dependent variable and age, education, digit span backward, ordering, and PPVT as independent variables. Only ordering entered the equation, accounting for 51% ($p < .0001$) of the variance in the error rates of these 25 participants, showing that this measure was the best overall predictor of how lexically and grammatically accurate participants' spontaneous speech was. However, the story within groups was somewhat different. Using the same stepwise regression protocol, the only predictor of the frequency of errors by the HE group was PPVT score, ($r^2 = .56, p < .001$), reflecting the fact that individuals with a larger vocabulary also made fewer errors in spontaneous speech. In the analysis of the PAD group's error rates, the number of semantic paraphasias in naming was added to the independent variables in the stepwise regression and was the only variable to enter the regression equation, accounting for 29% ($p < .10$) of the variance in scores.

Discussion

These analyses confirm the reports of Obler (1983) and others that both individuals with PAD and HE adults make errors on closed-class words and morpho-syntax, as well as on pronouns and open-class words. The fact that the distribution of errors across categories does not differ between participants with PAD and HE adults suggests that the difficulties experienced by speakers with PAD in speech may be an exaggeration of speech error patterns in healthy aging.

The finding that omission errors were associated with closed-class words while substitution errors affected primarily open-class words is not unique. In fact, it parallels reports from the aphasia literature (e.g., Bates & Wulfeck, 1989; Butterworth & Howard, 1987) and from connectionist models looking at issues of semantic and grammatical representation (Allen & Seidenberg, 1999; Plaut & Shallice, 1993). This issue is discussed in the Conclusion.

The best overall predictor of errors in spontaneous speech was the ordering measure, which is logical when considering the demands of this task compared to those of spontaneous speech. In both exercises, people must activate lexical items and then order them into a particular sequence based on their inherent characteristics (e.g., numerical, calendrical, or syntactic). Within

³This analysis was computed on the total error rate because the number of overall errors was very small and the distribution of errors across categories was relatively even in both groups.

each group, semantic measures were the best predictors of error frequencies. HE adults' error rates were predicted by the size of their vocabulary (which was not related to years of education), and the PAD group's error rates were predicted by the number of semantic paraphasias they had made on a 96-item naming test. It is important to realize that PPVT measures a different quantity in HE adults and those with PAD. The scores of individuals with PAD will necessarily reflect the degree of the damage in the semantic network as applied to the baseline vocabulary of the speaker.⁴ As such, PPVT might be interpreted as a measure of the current state of a semantic network, but not as a measure of semantic impairment or premorbid vocabulary for individuals with PAD, so the lack of relationship between this measure and error rates in the speech of speakers with PAD is not surprising. The relationship between error frequency in spontaneous speech and the number of semantic paraphasias in naming for participants with PAD suggests that these error types share a common source that is unaffected by premorbid vocabulary, which we suspect is semantic impairment.

These results cannot be explained by Garrett's strictly modular theory of speech, which would have predicted an interaction between group and error category, with the frequency of morphosyntactic and closed-class errors remaining the same between groups and only the frequency of open-class and pronoun errors being elevated in the speech of the group with PAD. This is clearly not the case, as individuals with PAD made more errors of all four types than did HE adults. Consequently, these data do not support a theory of speech production such as Garrett's—unless both the lexical and the grammatical processors are assumed to be impaired.

Our analysis does not rule out Levelt's theory (1989), which suggests that some closed-class words, such as modals and locational prepositions, are semantically represented, whereas others, such as auxiliary verbs and determiners, are syntactically represented. In an uncontrolled task such as spontaneous speech, it is difficult to directly compare the frequency of errors on purely grammatical versus semantically represented closed-class words due to intersubject variability of topic, word, and structure choice. That is, because speakers freely choose the topics and structures they produce, they can avoid lexical and grammatical structures that are difficult for them and thus not produce enough of the target constructions for meaningful comparison. Spontaneous speech may not be ideal data for analysis from another

perspective; it is possible that the closed-class errors in spontaneous speech might result from the attentional and linguistic demands required by spontaneous conversation. An average conversation requires speakers to simultaneously create a meaningful message, access appropriate lexical items, provide an appropriate sentence frame, and maintain pronoun reference, while they are also attempting to comprehend their conversational partner and all that that entails (Daneman & Greene, 1986). To address these issues, we have constructed the task in Experiment 2, which minimizes lexical access, discourse requirements, and context maintenance while simultaneously emphasizing closed-class word and morphosyntactic production.

Experiment 2: Constrained Production

As discussed above, spontaneous speech, for various reasons, does not assess whether speakers are able to correctly use all types of grammatical structures and closed-class words in a sentence, especially purely grammatical elements, such as articles and auxiliary verbs. Experiment 2 was designed to evaluate closed-class word use by asking participants to provide grammatical closed-class words to transform a set of three words, a verb form and two nouns, into a grammatical sentence. Thus, all the open-class words a participant needed for a sentence were provided, thereby minimizing lexical access demands as well as the memory and attentional demands imposed by aspects of conversation, such as reference tracking and tense coherence. Also in this task, speakers must assign thematic roles to the noun stimuli and distribute them, the verb, and the appropriate closed-class items to their proper positions in a sentence frame, thereby testing some minimal aspects of morphosyntactic processing. Based on these factors, we predicted that errors on pronouns and open-class words would be minimized and errors affecting morphosyntax and closed-class word use would predominate. However, certain characteristics of the task may minimize the opportunity for morphosyntactic errors; for example, there is no context over which tense coherence must be maintained, and the task strongly encourages the production of single-clause sentences. Thus, intrasentential tense errors and missing matrix or subordinate clauses should be few.

Methods

Participants

The same 10 individuals with PAD and 15 HE adults described in Experiment 1 participated in this experiment.

⁴This point is particularly relevant here since our PAD participant with the highest PPVT score had been a NASA engineer and president of the local MENSEA chapter and likely had a larger premorbid vocabulary than the majority of the participants.

Procedure

This task was part of the same battery of tests described above, which was completed over five sessions for participants with PAD or in one session for HE adults. Responses were audiotaped; transcription and error tabulation methods were identical to those described in Experiment 1. Interrater reliability remained high ($r = .88$). The sentence selected for scoring was the best response offered, which was usually but not always the final one.

Materials

In order to best assess the production of grammatical morphemes such as auxiliary verbs, determiners, and grammatical prepositions, this task, based on a task created by Ferreira (1994), was designed to encourage the production of passive sentences. Stimuli included a verb in the prominent, left-most position followed by two nouns arranged one above the other in 24-point Helvetica type on 5 in. \times 8 in. index cards, as shown in Figure 2. The verb was always the past participle of a verb from one of the three types described below, and the nouns were either two common names (e.g., Susan or Mike) or an inanimate noun (e.g., movie, toy, meeting) and a name. Each inanimate noun was a highly appropriate argument for a particular verb so that a semantic connection between them would be easy to make, such as poured/milk, thrilled/music, inspired/sermon, grown/roses. Noun arrangement varied so that a third of the stimuli showed a name above a name, a third positioned a name above an inanimate noun, and a third of the stimuli showed an inanimate noun above a name. The fourth possibility, two inanimate nouns, was not used because one of the verb types requires at least one animate argument.

There were three types of verbs: a control verb type and two verb types chosen particularly to encourage production of passive sentences. The control verb type, regular verbs, had identical past participle and simple past tense forms, and, in a simple active sentence,

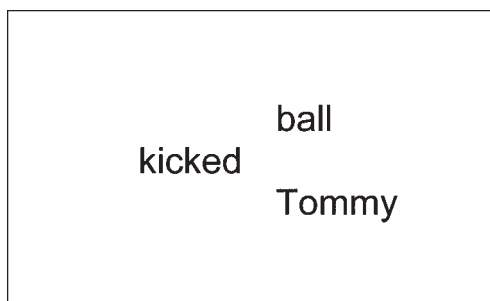
assigned the thematic roles agent and theme to its subject and object, respectively. This category included verbs like *bumped*, *carried*, and *poured*. The second type of verb, Theme-Experiencer verbs, assigned the thematic role theme to its subject and experiencer to its object in a simple active sentence; thus, active sentences took the form “inanimate noun—verb—animate noun” (e.g., “The movie shocked Sarah”). All of these verbs had equivalent phonological forms for the simple past and the past participle and came from the semantic category of “amuse” verbs (Levin, 1993, p. 189), for example, *surprised*, *shocked*, and *annoyed*. The last verb type consisted of transitive verbs with irregular past participles, such as *torn*, *thrown*, and *forgotten*; thus, for these verbs the simple past and past participle forms had distinct phonological forms. All of the irregular verbs assigned thematic roles in the same way as the regular verbs: the subject was the agent, and the object was the theme in an active sentence. When stimuli included irregular verbs (e.g., “thrown plate Lisa”), the morphological form of the verb forced speakers to produce a complex verb phrase, such as an active perfect (i.e., had thrown), a passive (was thrown), or a deverbal adjective (i.e., the thrown plate). A full list of stimuli is located in the Appendix.

Stimuli were divided into two lists of 27 items, each of which began with four practice trials and included three examples of each of the nine conditions (three verb types by three noun orders). Stimuli were pseudorandomly ordered so that no more than two of any one condition appeared consecutively. The order of list presentation varied across participants. Twenty-two of 25 participants completed both lists; 2 HE adults and one with PAD received only one list, but did not make errors on the task. Errors are reported as mean number of errors per person.

Participants were handed the index cards containing the stimuli one at a time and were asked to make up a grammatical sentence that included all three words. All participants were told (sometimes repeatedly) that they were allowed to add other words to make a sentence “make sense” or “sound better.” No time limits were placed on responses.

Scores from the working memory and semantic measures in Experiment 1 were also used in this experiment.

Figure 2. Sample of the stimuli in Experiment 2.



Results

Recall that this constrained production task provided participants with the orthographic forms of the open-class words they were to use in a sentence. None of the participants had difficulty reading these words. Although HE adults found this to be an easy task (mean

percent grammatical responses = 98.5%), individuals with PAD had more difficulty with it (mean percent correct 86.3%, $t(23) = 2.591$, $p < .02$). The most common errors were omissions of required closed-class words, for example, “Albert’s toy broken” (missing an auxiliary verb) and “Gary had chosen restaurant” (missing determiner). Participants also used incorrect closed-class words, as in “Linda was disgusted of the novel” and made morphosyntactic errors, as in “Robert terrified the fire” (incorrect argument structure) and “Either Ned or Kelly ignored each other” (incorrect reflexive use). There were also a few open-class and pronoun errors, such as “Frank had driven Maggie upset” (open-class substitution, target “crazy”) and “Lisa had thrown the plate and broken” (missing pronoun).

The prediction that the frequency of pronoun and open-class word errors would be minimized was correct, since only four of each were produced by the 25 participants. Morphosyntactic errors were more common in both groups, although individuals with PAD made significantly more of these errors than HE adults (PAD $M = .70$ /person, HE $M = .33$ /person; $t(23) = 3.041$, $p < .01$). In contrast to these relatively moderate error rates, the frequency of closed-class errors was much higher, especially among participants with PAD (PAD mean = 5.90/person, HE mean = .47/person). Further examination of the data revealed that 3 of the 10 participants with PAD were responsible for 86% of the closed-class errors. These 3 individuals produced 21, 15, and 11 closed-class word errors in 54 trials, 98% of which were omissions. This tendency was so extreme that some of their responses appeared agrammatic. For instance, “Jim lost game” and “Movie chosen by Gary” were interspersed with grammatical responses, such as “Rick studied the notes.” Considering the number of errors made by these 3 people, we questioned if they had understood the task. The majority of their responses were grammatical (range 59–81%), and these responses were interspersed with ungrammatical ones, including four to six completely correct passive sentences and one to three correct responses in the perfect aspect. Based on this, it appeared that these 3 understood the task. Six of the 7 other participants with PAD also produced closed-class errors, though at a much lower frequency (1–5 errors) than the 3 people discussed above, but only 4 HE adults made closed-class errors on this task. To compare the closed-class error between groups a nonparametric Mann-Whitney rank comparison test was used to avoid the biasing effects that the three unusually high closed-class error rates might have on a mean comparison. This test confirmed that individuals with PAD made more closed-class errors than HE adults ($U = 23.50$, $p < .005$).

The 3 individuals with PAD who omitted so many closed-class words were compared to the remaining 7

participants with PAD on age, education, MMSE, working memory, and semantic measures to determine whether they differed in any measurable way from the rest of the group. They fell well within the range of the other 7 PAD participants on these measures.

The best predictor of error rates by all participants on this task was the number of errors per 100 words in spontaneous speech ($r^2 = .70$, $p < .0001$), reflecting the fact that, across the two groups, speakers who made the most errors in constrained speech also made more errors in spontaneous speech. Working memory and PPVT did not enter into the regression. Within each group, different variables predicted performance. The best predictor of performance by HE speakers on this task was digit span backward, which accounted for 27% of the variance in error rates ($p < .05$). The best predictor of scores within the PAD group was the number of errors in spontaneous speech, which accounted for 77.7% ($p < .001$) of the variance in scores of this group. As in spontaneous speech, the number of semantic paraphasias in naming accounted for 38% of the variance in scores, but it had no effect once the number of errors in spontaneous speech was allowed to enter the equation.

Discussion

The goal of Experiment 2 was to determine whether individuals with PAD could provide the necessary grammatical closed-class words, such as determiners and auxiliary verbs, to make a grammatical sentence out of three prespecified, open-class words. The results showed that individuals with PAD were significantly impaired at accomplishing this task compared to HE adults. This suggests that individuals with PAD not only have production difficulties with semantically represented words like nouns, verbs, locational prepositions, and modals, as predicted by Levelt’s theory, but may also experience difficulties with the production of purely grammatical closed-class words (e.g., determiners and auxiliary verbs) in certain circumstances.

Individuals with PAD also produced more morphosyntactic errors than did HE adults, confirming the prediction that morphosyntax use would be affected in this task. This can be interpreted in at least two ways: (1) PAD may actually lead to a mild morphosyntactic impairment in addition to the semantic impairment or (2) PAD may lead to difficulty accessing specific linguistic information, whether it is semantic or grammatical.

There was a strong relationship between error rates in spontaneous and constrained speech across both groups, but especially among participants with PAD. The number of semantic paraphasias in naming accounted for nearly the same amount of variance in scores in both

tasks, but it did not predict errors in the constrained task when the error rate in spontaneous speech was allowed to enter first. Therefore, it appears that a common factor may underlie off-target naming responses and error rates in both speech tasks, but this underlying factor contributes more to error variance in spontaneous and constrained speech than to naming errors. For HE adults, who have no linguistic impairments, working memory predicted performance on this task.

An unexpected finding of this experiment was the exceptionally poor performance of 3 individuals with PAD. To our knowledge, agrammatic speech has never been reported for speakers with mild PAD in any task. The fact that they did not differ from the rest of the group on demographic, cognitive, or semantic measures suggests that they may represent the extreme tail of the distribution of possible language impairments at the mild stage of PAD. This group is discussed in more depth below.

General Discussion

In this study we have documented patterns of errors in the spontaneous and constrained speech of individuals with PAD and healthy older speakers. These patterns suggest that the nature of the task exerted a strong influence on the type of errors produced. In both tasks, people with PAD made errors in all aspects of language that they were required to generate themselves. In spontaneous speech, speakers must supply all lexical items (open and closed class), deictic references, and morphosyntax, and there were errors on all of these. Furthermore, Experiment 1 demonstrated that the distribution of errors made in spontaneous speech did not differ between the PAD and healthy groups: both groups made errors in all four categories. Though it is not surprising that participants with Alzheimer's disease made more open-class word and pronoun errors than healthy older adults, it is interesting that they also made more errors on closed-class words and morphosyntax than healthy older speakers. These findings conflict with previous reports of relatively preserved morphosyntax in the spontaneous speech of individuals with PAD (Bayles, 1982; Kirschner, 1982; Patel & Satz, 1994; Schwartz et al., 1979). However, this is not the first report of morphosyntactic errors in this population (Altmann et al., 1995; Kempler et al., 1987; Obler, 1983; Obler & Gjerlow, 1999), although it may be the first published quantitative analysis of them. The primary challenge in the constrained speech task in Experiment 2 was to generate appropriate closed-class items and morphosyntax to form a grammatical sentence when open-class word choice was constrained by the stimuli. As predicted, the majority of errors by individuals with

PAD in Experiment 2 affected grammatical closed-class words, with fewer errors on morphosyntax, and almost no errors on pronouns and open-class words. Considering the different distribution of errors, the strong correlation between error rates in the two tasks is particularly interesting and supports the hypothesis that the nature of the task affects both the type and quantity of errors in these tasks. Task effects are also found in the performance of the healthy older adults in that vocabulary size as predicted by PPVT scores predicted error rates in spontaneous speech, but working memory predicted error rates in the constrained production task, which suggests that the ability to activate and manipulate verbal data is crucial in performing this task. Along similar lines, we interpret the factor underlying error rates in the speech-production tasks and semantic paraphasias as the degree of degradation within the linguistic network, which would impair the speaker's ability to quickly and accurately activate lexical and grammatical information.

These results cannot be easily explained by modular models of speech production (e.g., Garrett, 1980, 1984), which predict that the speech of individuals with an impaired semantic processor should contain errors solely on open-class words and perhaps pronouns. This clearly does not describe the spontaneous speech of the participants with PAD in Experiment 1 who produced more errors in all categories than did healthy older adults. On the other hand, speech-production theories that distinguish between semantically encoded and syntactically encoded closed-class items (Levelt, 1989) cannot account for the difficulties with purely grammatical closed-class words experienced by participants with PAD in Experiment 2 unless there is also a mild syntactic impairment affecting their performance.

It is not the intention here to argue for a separate closed-class word or morphosyntactic impairment in PAD. Rather, it appears that the most parsimonious explanation of these results is that closed-class words, and perhaps morphosyntax, are vulnerable to errors from the same impairments that affect pronouns and open-class words—failures to fully activate lexical representations. We believe that these results are best accounted for using a model of speech production in which words of all types are accessed by the activation of features encoding semantic and grammatical information (Allen & Seidenberg, 1999; Altmann, 1998; Bates & Wulfeck, 1989; Goodglass & Menn, 1985). In these models, closed-class words differ from open-class words in the number, type, and interconnectivity of their features. Open-class words are posited to have rich semantic representations that consist of two types of features, features that are shared among members of a semantic category (e.g., all fish would share the features HAVE SCALES, HAVE FINS, SWIM,

BREATHE WITH GILLS) and features that serve to distinguish a particular item from others in the same category (e.g., the word *catfish* may have features that indicate BOTTOM-DWELLING and HAS WHISKERS) (Devlin, Gonnerman, Andersen, & Seidenberg, 1998; Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997). Crucially, features that are shared between open-class words from the same category are strongly interconnected due to the frequency with which they are accessed together. These interconnected or intercorrelated features serve to reinforce or boost the activation of the entire core feature set when activation is incomplete or weak. When activation within the system is limited or noisy as a result of pathology or even divided attention, intercorrelated features can still reach threshold due to their interconnections, whereas distinguishing features are less likely to reach threshold, leading to the substitution of a superordinate term or related word for the target. This theory parallels that of Smith et al. (1995) and Kempler et al. (1998) discussed earlier, in that the most frequently accessed lexical information (i.e., the shared, interconnected features) would be available most quickly, whereas other, lower-frequency features would be available later or perhaps not at all. This would result in the substitution of a related or superordinate word, accounting for the inaccurate and empty speech in PAD.

Closed-class word representations can be described using the same model. They are posited to have very small feature sets that are activated very quickly as a result of their exceedingly high frequency (Bock, 1989). Since there is little overlap in meaning between members of the closed classes (Bates & Wulfeck, 1989), any set of intercorrelated features is very limited, leading to semantic representations that consist, in essence, of small sets of distinguishing features. With few core, intercorrelated features to boost activation levels, any weakness or incomplete activation of the features of a closed-class word may lead to *no* word being clearly activated, resulting in an omission error rather than the substitution of a related word. This makes closed-class words extraordinarily dependent on the strength and clarity of the initial activation. Thus, when the ability of the linguistic system to fully and accurately activate semantic representations is compromised, such as in PAD or aphasia, the model predicts that closed-class words should be vulnerable to omission errors, but words with richer semantic representations, such as nouns or verbs, should engender more substitution errors. Indeed, this is exactly the pattern of omissions and substitutions reported for both groups in Experiment 1.

With respect to morphosyntax, inflected forms of open-class words would differ from each other by only a feature or two, such as PLURAL, TENSE, or CASE (Bates &

Wulfeck, 1989). Since grammatical information is also featural, it will be subject to the same vagaries of featural activation that other lexical representations are. Thus, noise or damage in the linguistic system can cause morphosyntactic errors exactly the same way it causes open-class errors—less-activated distinguishing features either do not reach threshold or fall below threshold activation before articulation, and so the inflection on the stem is substituted or omitted. Consequently, we would expect inflectional errors to be present in the speech of individuals with a compromised semantic system, and indeed, these errors constituted 88% of all the morphosyntactic errors in the spontaneous speech of individuals with PAD in Experiment 1.

How can we account for the performance of the 3 individuals with PAD who had such extraordinary difficulties providing closed-class words in context in Experiment 2? Converging evidence from traditional aphasiology, ERP studies of activation patterns associated with open- and closed-class words (Neville, Mills, & Lawson, 1992; Pulvermüller, Lutzenberger, & Birbaumer, 1995), neuroimaging studies of primary progressive aphasia (Hodges & Patterson, 1996; Kempler, Curtiss, Metter, Jackson, & Hanson, 1991), and semantic dementia (Breedin & Saffran, 1999) indicates that Broca's area is not the only cortical area crucial to grammatical processing. These studies suggest that grammatical information may be distributed throughout the entire perisylvian region. If this is indeed so, it is possible that these 3 individuals with PAD simply have more random damage in the perisylvian region than the norm for individuals with PAD at the mild stage of the disease. Unfortunately, no imaging data is currently available on these people to test this hypothesis.

These findings and the speculations based on them suggest several areas for further research. First, the argument above makes strong, testable predictions about what the responses of individuals with perisylvian versus extra-perisylvian damage should be on a constrained speech task such as the one presented here. In addition, the model presented here predicts that persons with aphasia manifesting as mild semantic impairment will make more errors in spontaneous speech than matched individuals on the four error types used here, including closed-class words and morphosyntax. This has been partially documented; Zaroff, Wulfeck, Bates, and Reilly (1997) report that individuals with anomia speech, who are usually described as having difficulty with open-class words, produce grammatical errors in spontaneous and constrained speech. From another viewpoint, the constrained production task described here tests speakers' awareness of the grammatical forms required in certain sentence types, particularly perfect and passive sentences, and so may prove useful in

uncovering gaps in the linguistic knowledge of individuals who have recovered from aphasia or adults who had been diagnosed with specific language impairment as children. Finally, considering that the constrained production task used in Experiment 2 was particularly difficult for individuals with PAD (see also Altmann, 1998), it may prove to be a useful tool for distinguishing between healthy older adults and those in the early stages of mild cognitive impairment from probable Alzheimer's disease or primary progressive aphasia.

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Contact author: Lori Altmann, PhD, Gerontology Center, University of Kansas, 1000 Sunnyside Avenue, Lawrence, KS 66045-7555. E-mail: laltmann@ukans.edu

Appendix. Experiment 2 Stimuli.

Regular (Verb–top noun– bottom noun)	T-E (Theme-Experiencer) (Verb–top noun– bottom noun)	Irregular (Verb–top noun– bottom noun)
bumped–Liz–Mary	depressed–Ken–Lois	driven–Maggie–Frank
repeated–Jim–Gary	amused–Nancy–Kevin	shaken–Albert–Joan
avoided–Jane–Ruth	annoyed–Ned–Kelly	beaten–Don–Charlie
carried–Becky–Jill	bored–Paula–Scott	drawn–Amy–Lisa
found–Mike–Susie	tempted–Dan–Terry	forgotten–Cathy–Joe
stopped–Greg–Bob	confused–Laura–Tim	seen–Larry–Mike
taught–history–Susan	shocked–Sarah–movie	eaten–Bill–cake
delayed–meeting–Frank	excited–Randy–trip	taken–Diane–pill
loved–cookies–Lynn	thrilled–Betsy–music	broken–Albert–toy
caused–uproar–David	terrified–Robert–fire	chosen–Gary–restaurant
poured–milk–Betty	inspired–Karen–sermon	hidden–Fran–candy
typed–letter–John	frightened–Grace–thunder	stolen–Henry–stereo
climbed–Debbie–ladder	disgusted–novel–Linda	torn–pants–Jack
spilled–Tom–juice	baffled–machine–Jeff	woven–cloth–Gail
lost–Jim–game	enraged–program–Ben	written–book–Peter
warmed–Sally–bread	delighted–gift–Ann	shown–movie–Paul
studied–Rick–notes	surprised–news–Donna	thrown–plate–Lisa
explored–Sam–cave	startled–noise–Ron	grown–roses–Pam