Why Do Alzheimer Patients Have Difficulty with Pronouns? Working Memory, Semantics, and Reference in Comprehension and Production in Alzheimer's Disease

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Three experiments investigated the extent to which semantic and working-memory deficits contribute to Alzheimer patients' impairments in producing and comprehending referring expressions. In Experiment 1, the spontaneous speech of 11 patients with Alzheimer's disease (AD) contained a greater ratio of pronouns to full noun phrases than did the spontaneous speech produced by 9 healthy controls. Experiments 2 and 3 used a cross-modal naming methodology to compare reference comprehension in another group of 10 patients and 10 age-matched controls. In Experiment 2, patients were less sensitive than healthy controls to the grammatical information necessary for processing pronouns. In Experiment 3, patients were better able to remember referent information in short paragraphs when reference was maintained with full noun phrases rather than pronouns, but healthy controls showed the reverse pattern. Performance in all three experiments was linked to working memory performance but not to word finding difficulty. We discuss these findings in terms of a theory of reference processing, the Informational Load Hypothesis, which views referential impairments in AD as the consequence of normal discourse processing in the context of a working memory impairment.   © 1999 Academic Press

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The speech of patients with Alzheimer's disease (AD) is often described as ''empty'' as it contains a high proportion of words and utterances that convey little or no information (Hutchinson & Jensen, 1980; Kempler, 1995; Nicholas, Obler, Albert, & Estabrooks-Helm, 1985; Ripich & Terrell, 1988; Ulatowska, Allard, & Donnell, 1988). For example, AD patients produce a low ratio of propositions to words and the thoughts they express are often left incomplete (Hier, Hagenlocker, & Shindler, 1985; Ripich & Terrell, 1988). However, perhaps the single most obvious characteristic of AD patients' so-called empty speech is the overuse of ''empty words'' (''thing,'' ''it,'' ''do'') (Kempler, 1995; Ripich & Terrell, 1988; Ulatowska et al., 1988). Although such empty words are common in language (indeed most of them are high frequency words), their use is generally restricted to particular circumstances. For example, pronouns (e.g., ''it,'' ''he'') are typically used when the referent is highly salient for both the speaker and the listener, while full noun phrases (NP; e.g., ''the dog''), which are more informative, are used when the referent is not highly salient in the discourse (Almor, in press; Ariel, 1990; Gundel, Hedberg, & Zacharski, 1993; Marslen-Wilson, Levy, & Tyler, 1982). In contrast to the restricted use of pronouns in normal speech, the use of pronouns by AD patients is frequent and often inappropriate (Kempler, 1995; Ripich & Terrell, 1988; Ulatowska et al., 1988). Revealing the causes of this pronoun overuse in AD will not only contribute to our understanding of the language deficits of AD but will also allow us to propose ways of improving communication between AD patients and their caregivers.

The fact that reference is often considered a discourse level process has led several authors to propose that pronoun overuse is the consequence of failing to follow discourse conventions. For instance, Hutchinson and Jensen (1980) argue that AD patient's empty speech in general is due to a pragmatic

deficiency in discourse structuring ability, as is evidenced by the smaller than normal number of ideas expressed by these patients in each conversational turn. Addressing the overuse of pronouns specifically, Ripich and Terrel (1988), Ulatowska and Chapman (1995), and Ulatowska et al. (1988) allude to a pragmatic impairment in the ability to generate coherent and cohesive discourse and in particular to take into account the informational needs of the addressee. While any such discourse level impairment certainly would disrupt language production, it is hard to assess the contribution of any of these impairments to AD patients' empty speech without first assessing the contribution of some more basic cognitive impairments that may themselves underlie discourse level deficits. The purpose of the research presented here is to investigate the extent to which two such basic impairments, a lexical semantic impairment and a working memory impairment, are responsible for referential deficits in AD.

Semantic impairments could cause the empty speech associated with AD. It is well known that most AD patients experience a word finding difficulty that becomes worse as the disease progresses (Bayles, Boone, Tomoeda, Slauson, & Kaszniak, 1989; Huff, 1988; Kempler, 1995; Kempler, Curtiss, & Jackson, 1987). This word finding difficulty is not merely the result of general forgetfulness, which may make patients forget what they wanted to refer to, because patients often exhibit word finding difficulty even in the presence of a referent or its picture (Bayles et al., 1989) and because patients often have more difficulty with referents from only specific semantic categories (e.g., living things; Gonnerman, Andersen, Devlin, Kempler, & Seidenberg, 1997). Rather, the word finding difficulty is likely caused by a genuine semantic impairment in processing lexical information from semantic long-term memory (Chertkow, Bub, & Seidenberg, 1989; Hier et al., 1985; Huff, 1988).[2] Indeed, as could be expected in any impairment with a lexical origin, the word finding deficit associated with AD (as well as other populations) is frequency-sensitive: The production of high-frequency words is relatively preserved while the production of low-frequency words is impaired (Balota & Ferraro, 1993; Patterson, Graham, & Hodges, 1994; Shuttleworth & Huber, 1988).

It can be argued that this basic semantic/word finding deficit leads directly to empty conversational speech in the following way. In the face of failure to activate the intended phonological information (the target word) during sentence production, AD patients, who as a group demonstrate preserved knowledge of sentence (grammatical) structure (Hier et al., 1985; Kempler,

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[2] Here we are distinguishing between semantic long-term memory (e.g., general knowledge of word meaning), episodic long-term memory (e.g., the representation of biographical events; Tulving, 1984, 1986), and working memory, where various kinds of information, including semantic information, are maintained during cognitive operations (Baddeley, 1992; Carpenter, Miyake, & Just, 1994; Waters & Caplan, 1996).

Almor, Tyler, Andersen, & MacDonald, 1998b; Kempler et al., 1987; Schwartz, Marin, & Saffran, 1979; Waters & Caplan, 1997; Whitaker, 1976), substitute a higher frequency, easily retrievable, and grammatically valid replacement for the target word that they cannot find. Under this view, empty words (''thing,'' ''do,'' ''he,'' ''it,'' etc.) are successfully and relatively easily activated precisely because they are high in frequency and allow the patients to produce fluent and grammatical sentences in the presence of debilitating semantic deficits.

Although this ''semantic impairment hypothesis'' may seem plausible at first glance, it nevertheless faces several problems at both the empirical and the theoretical levels. Empirically, previous attempts to demonstrate a link between word finding difficulty and empty speech have been largely unsuccessful. For example, Nicholas et al. (1985), who examined AD patients' picture descriptions, found that only 1 of 14 measures of discourse emptiness correlated with patients' naming scores on the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1976). Nicholas et al. also examined picture descriptions produced by anomic aphasics, whose speech is often described as empty. They found that these patients' scores on the Boston Naming Test were not correlated with any of the 14 measures of discourse emptiness. The results of the Nicholas et al. study thus suggest that there is little if any consistent relation between semantic impairment as gauged by the Boston Naming Task, and empty speech.

Theoretically, in drawing on the well-established deficits in confrontation naming to explain the phenomenon of empty conversational speech, the semantic impairment hypothesis overlooks some crucial differences between the requirements of picture naming (the measure by which semantic deficits are usually demonstrated) and making reference in conversation (where empty speech is observed). In confrontation naming, visual information (the object to be named) is used to activate phonological information (the name) from semantic long-term memory. However, in natural conversation, word production seldom happens in such limited linguistic context with strong visual cues. The requirements of the linguistic context and the lack of visual cues create other cognitive demands. For example, producing words in conversation often requires remembering what is to be said while processing preceding speech. (A speaker meaning to say ''Yesterday, I went to see my son'' has to remember the referent ''my son'' as s/he says ''Yesterday, I went to see.'') In addition, natural conversations contain many repeated mentions of the same referents because repeated anaphoric reference is an important part of coherent and well structured discourse, in which topics typically span several utterances (Givon, 1976; Gordon, Grosz, & Gilliom, 1993; Marslen-Wilson et al., 1982; van Dijk & Kintsch, 1983). Because speakers are required to maintain all this information while they process the intervening material, word production in conversation is crucially dependent on working memory function (defined as the ability to maintain various kinds of informa-

tion during cognitive operations; Baddeley, 1992; Carpenter, Miyake, & Just, 1994; Waters & Caplan, 1996). This raises the possibility that an impairment in working memory may play an important role in producing empty conversational speech, a proposal we refer to as the ''working memory impairment'' hypothesis.

The claim that overuse of high-frequency words may be due to a difficulty in maintaining active representation in working memory is consistent with the role of working memory in performing a variety of tasks required for language processing (Carpenter et al., 1994; Daneman & Carpenter, 1980; MacDonald, Just, & Carpenter, 1992; Waters & Caplan, 1996), especially discourse and reference processing (Almor, in press; Ariel, 1990; Givon, 1976; Gordon et al., 1993; van Dijk & Kintsch, 1983), and the working memory deficits that are widespread in AD (Baddeley, 1992; Carpenter et al., 1994; Waters & Caplan, 1997). By this view, the use of high-frequency empty words may be the outcome of deteriorating semantic representation in working memory and not the result of a semantic impairment. The rapid degradation of semantic features in working memory, which could be the result of insufficient initial activation, abnormally rapid decay, or improper inhibition of competing information, could lead patients to produce a general term because, at the time of word selection, their semantic representation has already deteriorated to fit the general label better than any specific label. Indeed, in many theories of semantic impairment, the distinctive semantic features of any concept, which are the idiosyncratic properties distinguishing the concept from the rest of its category, are the most susceptible to damage (e.g., Gonnerman et al., 1997). In the absence of these distinguishing features, the representation of a concept (e.g., poodle) may become more like the representation of the category prototype (e.g., dog), and, with even further deterioration of semantic features, like the representation of the category's superordinate (e.g., animal). The fact that empty words are grammatically compatible with the context they appear in could be attributed to the high resilience of grammatical features to damage, as grammatical processing involves very high frequency features (e.g., gender, number).

In summary, because the semantic impairment hypothesis capitalizes on a deficit in activating lexical information, it predicts a strong link between empty speech and anomia. This prediction entails a strong correlation between measures of empty speech, such as the ratio of pronouns in all nominal references, and measures of anomia, such as performance in a picture naming task. In contrast, the working memory impairment hypothesis postulates that a deteriorating representation in working memory is a primary cause of empty speech in AD and thus predicts a link between empty speech and a working memory impairment. By this prediction, measures of empty speech, such as the ratio of pronouns in all nominal references, should correlate with measures of working memory performance, such as listening span (Daneman & Carpenter, 1980).

The two hypotheses are tested in three studies of AD patients' and healthy elderly controls' processing of nominal reference. Experiment 1 investigates the link between pronoun production and semantic and working memory deficits in AD patients and older healthy controls. Experiment 2 extends the two hypotheses to language comprehension in examining the ability of AD patients and healthy elderly adults to maintain an active representation of information that is necessary for processing pronouns in comprehension, and in testing for links between this ability and measures of semantic and working memory deficits. Experiment 3 compares the effect of pronouns and full NPs on the ability of AD patients and older healthy controls to maintain active representation of referents during comprehension and tests whether this effect is linked to either semantic and/or working memory deficits.

EXPERIMENT 1: PRONOUNS IN SPONTANEOUS SPEECH

Experiment 1 was undertaken both to establish that AD patients' empty speech is in fact apparent in their use of pronouns and other nominal references, and to assess whether pronoun use is related to a working memory impairment or to a semantic impairment. All the participants in this study also completed a set of tests designed to evaluate their semantic processing and working memory.

To obtain an indication of pronoun frequency in natural conversation, we compared transcriptions of spontaneous conversational speech produced by AD patients and those produced by age- and education-matched healthy controls. In contrast to other, more structured, language elicitation protocols such as the cookie-theft picture description (Goodglass & Kaplan, 1972), participants were only prompted to tell something about their own lives and had otherwise complete autonomy over the number of included referents and topics and the amount of information conveyed about these referents and topics.

Method

Participants. Eleven participants diagnosed with probable Alzheimer's disease and nine healthy age-matched normal controls (NCs) participated in this study. The Alzheimer participants were referred by the University of Southern California Alzheimer's Disease Research Center and the Alzheimer's Disease Diagnostic and Treatment Center at Rancho Los Amigos Medical Center. All AD participants met the NINCDS-ADRDA criteria for probable Alzheimer's disease (McKhann, Drachman, Folstein, Katzman, Price, & Stadlan, 1984). Results of neurological, laboratory (including computed tomography (CT) or magnetic resonance (MR) scan), and neuropsychological assessment failed to suggest other causes of dementia. The AD participants were mildly to moderately demented as gauged by the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975). All participants were native speakers of Standard American English. The healthy controls and AD participants were not significantly different in either age ($t(18) = 1.38$, $p = .19$) or years of education ($t(18) = -1.6$, $p = .14$). See Table 1 for participant information.

TABLE 1
Experiment 1 Participant Information

	MMSE			Age			Education		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
AD (*n* = 11)	21	2	16–24	80.7	6.8	64–89	15	2.3	12–20
NC (*n* = 9)	29.1	1.1	27–30	77	4.4	70–85	16.8	2.8	13–22

Procedure. Spontaneous speech data were collected at the beginning of testing sessions that were designed to collect data for unrelated experiments. To elicit speech, the experimenter prompted the participant for several biographical details, such as place of birth and family history. The participant was then given an opportunity to describe these biographical details through a conversation with the experimenter. Interviews were tape-recorded by the experimenter and were later transcribed twice, by different individuals. Any inconsistencies between the two transcriptions were resolved by consulting the recordings. As the main goal of the present analysis was to assess AD patients' and NCs' use of referring expressions, only complete words produced by the participant were included. Thus, the experimenter's part of the conversation as well as any participant-produced fillers (e.g., *umm, uh*) and incomplete word fragments (e.g., *the stu-, th-th-* before saying *the boy*) produced by the participant were eliminated from this analysis.

Semantic performance was assessed through the use of two tasks: (1) the Peabody Picture Vocabulary Test—Second Edition (PPVT; Dunn & Dunn, 1981), which is a single word picture pointing comprehension test; and (2) a picture naming task, in which participants were asked to name 96 black and white line drawings representing highly imageable, concrete, nouns from eight different semantic categories: animals, birds, fruits and vegetables, body parts, furniture, vehicles, clothing, and tools. Each category was represented by both typical and less typical exemplars (Rosch & Mervis, 1975). The PPVT was administered to all participants, and the picture naming task was administered to only the AD patients.

To assess linguistic working memory we developed a new task, month ordering. Pilot testing had demonstrated that Daneman and Carpenter's (1980) listening span task, which is very successful at discriminating linguistic working memory capacity in healthy participants, is too difficult for the AD patients. Like the listening span task, the month ordering task was designed to require simultaneous storage and manipulation of verbal information, because tasks that contain both storage and processing components have been found to be good correlates of language processing abilities, in contrast to tasks with minimal processing components, such as simple forward digit span (Daneman & Carpenter, 1980). In the month ordering task, participants were required to put into calendar sequence an increasingly long set of months presented out of calendar order. For example, in a given trial, a participant may hear: ''June, September, February,'' and should respond: ''February, June, September.'' This task creates similar working memory and processing demands to those involved in auditory language comprehension in that the participant must process a speech signal (the list of months), convert it to a semantic representation, and use this representation to order the input and formulate a response. The administration procedure for this task was adapted from Daneman and Carpenter (1980). There were four trials presented at each span level, starting with 2-month trials at the first level, and ending with trials containing 6 months at the fifth and last level. Testing was stopped after two trials at a span level were sequenced incorrectly. Participants could score from 0 to 20, which was the overall number of correct sequences.

Finally, to evaluate the possibility that any patterns in the data are a consequence of dementia severity, we assessed dementia severity by the standard Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975).

Results

Table 2 shows the mean and range of the total number of words from the narratives that were analyzed for both the AD and the NC participants. Although there were considerable differences in narrative size between individual participants, there were no group differences in the mean number of complete words produced in the narratives, $t(18) < 1$. For the analysis, all the nominal references from each narrative were listed separately. As we were primarily interested in the type of nominal reference used and not in issues of syntactic complexity, we did not consider relative clauses that modified nouns as part of the noun phrase, and thus any noun contained within such a relative clause was listed separately. For example, in the sentence: ''I remember our first house that my parents bought when I was five,'' the following nominal references were listed: *I, our first house, my parents, I.* Table 2 shows the mean number of nominal references produced in narratives of participants from the two populations and also the percentage of words that were included in nominal references in the total number of words in the narrative. The two populations were not different in the total number of nominal references coded in a narrative, $t(18) < .8$, nor in the proportion of words that were part of nominal references relative to the total number of words in the narrative, $\chi^2(1) < .9$. Thus, the two populations produced narratives that were not different in the total number of words, the number of nominal references, or the proportion of words within nominal references.

Type of referential expressions. Next we looked at whether the nominal references produced by the AD patients were in any way different than the nominal references produced by NCs. We classified all the nominal references in the narratives either as pronouns (any one of the following appearing independently and not as modifiers and determiners: *I, me, my, myself, you, yourself, we, us, ourselves, ourself, they, them, themself, themselves, it, itself, she, her, herself, he, him, himself, his*) or as other noun phrases. The results of this classification, summarized in Table 2, showed a significant difference between the kind of nominal references produced by the two groups. Whereas more than half of the nominal references produced by the AD patients were pronouns, only 42% of the nominal references produced by the NC participants were pronouns, $\chi^2(1) < .001$. Thus, although AD patients and NCs do not differ in their overall verbosity, as indicated by the similar sized narratives and the similar frequency of nominal references in their narratives, the two groups nevertheless tended to produce different proportions of pronouns vs other noun phrases. AD patients seemed to rely on pronouns more than any other form of nominal reference in their language production, whereas the healthy elderly did not.

Correlations with MMSE, semantic, and working memory impairment. To assess whether dementia severity, semantic impairment, and/or working memory impairment are linked to the increased use of pronouns, we con-

TABLE 2
AD and NC Narrative Size and Consistency

	Total No. of words in each narrative			No. of nominal references in each narrative			Percentage of words in nominal references			Percentage of pronouns in total nominal references		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
AD	466.5	331	143–1241	174	130	56–501	48	5	39–56	52	11	40–68
NC	432.2	100	251–643	163	60	87–252	50	6	44–62	42	8	29–54

ducted a series of correlational analyses on pronoun percentage in individual participants' narratives and scores on the MMSE, semantic, and working memory measures. Because we wanted to test for the relation between the various measures and pronoun use in general, we included the data from all participants, AD patients and NCs, in these analyses. Also, because we were testing the specific hypothesis that a larger impairment is related to an increased pronoun use, we used one-tail statistics. The outcome of these analyses was as follows. Dementia severity, as gauged by MMSE, did not correlate with pronoun preference, Pearson $r(19) = -.12, p < .4$. Similarly, semantic impairment gauged by PPVT and picture naming (AD patients only) did not correlate with pronoun percentage either, $r(19) = -.15, p < .3, r(10) = .005, p < .5$, respectively. In contrast, performance on the month ordering working memory task did correlate with pronoun preference in the predicted direction, $r(19) = -.4, p < .05$. The higher the score on the month-ordering task, the fewer pronouns produced.

To make sure that the lack of correlation between pronoun preference and MMSE, PPVT, and picture naming was not an artifact of too little or too much variability in these measures, we tested the correlations between MMSE, PPVT, picture naming, and month ordering. MMSE was not linked to PPVT score, $r(19) = .37, p < .131$, marginally linked to picture naming, $r(10) = .44, p < .09$, and significantly linked to month ordering, $r(19) = .6, p < .03$. PPVT was significantly linked to both naming, $r(10) = .72, p < .006$, and month ordering, $r(19) = .5, p < .02$. Finally, picture naming was marginally linked to month ordering, $r(10) = .42, p < .1$. Overall, all measures of dementia and semantic impairment correlated with at least one other performance measure (including the working memory measure), thus indicating that the lack of correlation between these measures and pronoun preference is not an artifact of too little or too much variability in these measures.

Discussion

This experiment showed that, as a group, mild AD patients were more likely than healthy controls to produce pronouns in spontaneous speech. On an individual basis, this tendency was found to be linked to working memory performance (month ordering), but not to measures of dementia severity (MMSE), or semantic performance (PPVT, and picture naming). These findings support the working memory impairment hypothesis—pronoun use increased with decreased working memory. In contrast, the semantic impairment hypothesis failed to gain any support—no relation was found between pronoun use and either measure of semantic impairment.

These findings are suggestive but they have an important limitation in that they are based on a rather coarse offline measure—the overall percentage of pronominal references in a narrative. This measure, which represents the

final outcome of language production, provides only indirect evidence regarding the actual processing involved in producing pronouns and other referential expressions. In previous research, we and others have shown that offline measures that are based on behaviors that are the final outcome of processing can yield very different results from online measures of the same processing (Tyler, 1992), especially with respect to the involvement of working memory (Kempler, Almor, & MacDonald, 1998; Kempler et al., 1998b). Although in the present case the measured final behavior is spontaneous language production in a relatively normal conversational context, it may still obscure some important factors that affect actual processing, most importantly, the activation of information in working memory during processing.

Moreover, the present evidence pertains only to language production and not to language comprehension. Although the semantic impairment hypothesis was not supported by the production data, it may still be viable for comprehension. Recall that the semantic impairment hypothesis attributes AD patients' preference for pronouns in production to a difficulty in activating lexical information for other words. In this view, the use of pronouns is relatively preserved even when the use of other lexical items is not. By the same token, it may seem plausible to expect the relative preservation of pronoun processing in comprehension—AD patients may show better comprehension when pronouns are used than when other referential forms are used because they may be hindered by the lexical processing required by nonpronominal expressions.

In contrast to this prediction of intact pronoun processing in AD patients' comprehension, the working memory impairment hypothesis predicts that pronoun processing in AD patients' comprehension should be impaired. The reasons are twofold. First, in order to fully process a pronoun, which contains only limited semantic information, listeners have to rely on semantic information in working memory. If that information is degraded, so would the ability to process pronouns that corefer with that information. Second, when a reference is repeated, it serves to reactivate the memory representation of the referent. Pronouns, due to their ''light'' informational content, would be less effective activators of memory representation than full NPs, which carry more information. This is because by many views of memory activation (e.g., Low & Roder, 1983), the greater the overlap between an input cue and the represented information, the greater the overall activation. When memory performance is degraded as in AD, the weaker activation generated by pronouns may be insufficient to elicit the representation necessary for successful comprehension.

The following experiments were undertaken to test AD patients' online comprehension of pronouns and full NPs and thus further elucidate these issues. Experiment 2 compares AD patients with healthy controls in their ability to maintain in memory the information required for processing pro-

nouns. Experiment 3 examines the effect of reference form (pronouns vs full NPs) on the ability of AD patients and healthy controls to maintain information in memory.

EXPERIMENT 2: PRONOUN COMPREHENSION

Experiment 2 employed a cross-modal naming paradigm (Marslen-Wilson, Tyler, & Koster, 1993; Tyler & Marslen-Wilson, 1977) to test participants' ability to maintain in memory the information necessary for processing pronouns during online language comprehension. Although proper use of pronouns is affected by many factors in the discourse and sentence context, successful processing of pronouns requires that the information conveyed in the pronoun is matched with information that is already held in working memory. For example, to process the pronoun *he,* a match is required with an active representation in working memory of a single male referent. A difficulty in maintaining active working memory representation, as postulated by the working memory impairment hypothesis, would result in reduced ability to process pronouns.

The cross-modal naming paradigm was chosen because it provides a close assessment of participants' online processing. Previous research has shown that mild to moderate AD patients can perform a cross-modal naming task quite easily and, furthermore, that their performance in this task with a wide range of grammatical violations is not different than that of healthy controls (Kempler et al., 1998a; Kempler et al., 1998b; Nebes, Boller, & Holland, 1986). In their cross-modal naming performance, AD patients show normal sensitivity to violations of number and gender agreement, argument structure, and pragmatic plausibility. Given this previous finding of AD patients' normal-like performance in this task, the questions in the present experiment are: (1) Would the requirement to retain information in working memory distinguish AD patients' performance from normal performance? and (2) Would performance in this experiment correlate with working memory performance, as predicted by the working memory impairment hypothesis, and/or with semantic performance, as predicted by the semantic impairment hypothesis?

Method

Participants. Ten participants diagnosed with probable Alzheimer's disease and 10 healthy age-matched controls participated in this study. Participants were recruited and selected as in the previous experiment and were native speakers of Standard American English. See Table 3 for participant information. Participants were tested at home or at the University of Southern California campus. Although patients and NCs differed in age and education, these differences did not quite reach statistical significance—age, $t(18) = 2$, $p < .07$; years of education, $t(18) = 1.97$, $p < .07$. However, because there were these small differences, we included the factors of age and education in all analyses.

TABLE 3
Experiment 2 Participant Information

	MMSE			Age			Education		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
AD ($n = 10$)	21	3.8	17–28	82	4.3	76–89	15	2.5	11–20
NC ($n = 10$)	29.4	1.1	28–30	78	4.2	70–84	17	1.9	14–22

Materials and procedure. In this experiment, the information that was to be retained was included in short paragraphs that were presented auditorially. Stimuli were generated by combining 20 such auditory paragraphs with two pronouns that were used as visual targets, one that constituted an appropriate coreferential continuation to the discourse fragment and one that did not. All items consisted of two full sentences followed by a final incomplete sentence fragment. The first sentence always introduced two entities, one plural and one singular (e.g., ''The children loved the silly clown at the party''), and the second sentence continued the same topic but did not mention either entity from the first sentence (e.g., ''The show was very funny.''). The final sentence fragment mentioned one of the entities and ended right before the other entity was likely to be mentioned (e.g., ''During the performance, the clown threw candy to''). This fragment preceded a visual target which was an appropriate coreferential continuation pronoun (''them'') in half of the trials and an inappropriate continuation pronoun (''him'') in the other half. (The paragraph ''The children loved the silly clown at the party. The show was very funny. During the performance, the clown threw candy to __'' would be more likely to end with the coreferential pronoun ''them'' than with the pronoun ''him,'' which would have to be interpreted as introducing a new entity by virtue of incompatible number.) The onset of visual target presentation was triggered by the end of the auditory fragment. Naming latencies for this visual target provide a measure of the degree to which participants are sensitive to the appropriateness of the pronoun. Because in similar experiments healthy young adults were slower to name an inappropriate pronoun than an appropriate one (e.g., Marslen-Wilson et al., 1993; Tyler & Marslen-Wilson, 1982), we expected older NCs to also show a similar pronoun appropriateness effect. However, if AD patients are impaired in their ability to maintain active representation of referents, they should exhibit reduced sensitivity to pronoun appropriateness compared to NCs. Overall, the experiment had two factors—Population (AD, NC) and Pronoun Appropriateness (appropriate, inappropriate).

Stimuli were digitally recorded using MacRecorder and a Macintosh computer in a sound-attenuated booth with a constant mouth-to-microphone distance of 8 inches. To avoid coarticulation cues, a standard filler word was recorded at the end of each fragment instead of the target word and then digitally excised. Each participant was tested in a quiet room, sitting in front of a Macintosh Classic computer. The experimenter was controlled by the PsyScope software package (Cohen, MacWhinney, Flatt, & Provost, 1993). Auditory stimuli were presented via a high quality loudspeaker, with volume adjusted to ensure that each participant could hear the stimuli adequately. Participants were asked to read the visual targets aloud as quickly and accurately as possible (Marslen-Wilson et al., 1993; Tyler & Marslen-Wilson, 1977). In order to assure that participants were paying attention to the stimuli (and not just reading the words aloud; see Tyler & Marslen-Wilson, 1977), we included an additional comprehension task: After naming each target word, control subjects were asked whether the word was a good or bad continuation of the sentence. Pilot testing with AD subjects indicated that this secondary task was so distracting that they could not produce accurate and fast responses to both the primary (word reading) and the secondary tasks. Therefore, an alternative directed attention task was developed for the AD subjects: they were asked yes/no comprehension questions for 25% of the context sentences. This secondary task successfully directed their
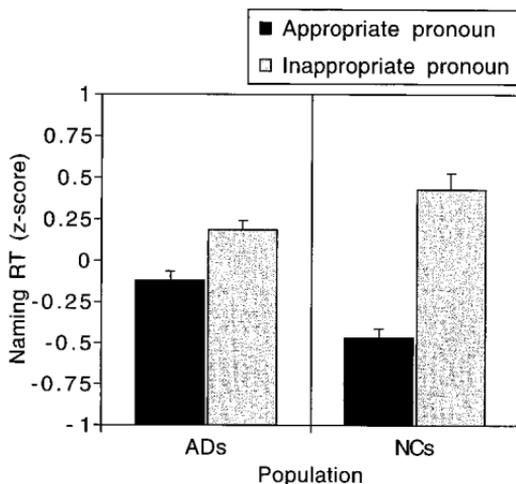
FIG. 1. Pronoun naming latencies in Experiment 2.

attention to the stimuli and did not interfere with their ability to perform the primary task. Responses to this secondary task were not scored, but merely served to encourage the participants to integrate the context fragment and the visual target.

We tested participants in four separate sessions, a minimum of 1 week apart for the AD patients and 3 weeks apart for the control participants. The stimuli presented in each session were counterbalanced so that a participant never heard the same discourse fragment more than once in a single session and therefore never encountered an appropriate and inappropriate version of the same item in the same session. Stimuli were pseudorandomly mixed with fillers from other experiments using different sentence structures. Twenty percent of the items were from this experiment and 80% were fillers. In half of the items, the visual target was a good continuation of the auditory context, and in the other half it was not. Ten practice items began each session.

MMSE, month ordering, and picture naming were administered to participants in this experiment using the same procedure and materials as in the previous experiment. Due to the small variance in PPVT performance in the previous experiment, it was not included in this experiment. Instead, picture naming was administered to both AD patients and healthy controls.

Results

Naming latencies. Naming latencies were analyzed after eliminating all machine and reading errors (6.3% of responses) and latencies beyond 3 standard deviations from a participant's mean naming latency in each session (affecting a further 1% of the data.) Next, naming latencies were normalized by transforming them into z scores based on each participant's mean and standard deviation in each session. This minimized irrelevant effects due to variations in the speed of individual participants across sessions and established a common basis for evaluating responses of different participants from different populations. These normalized mean naming latencies are shown in Fig. 1.

A 2×2 ANCOVA, Population by Visual Target Appropriateness with

covariates Age and Education, found a main effect of target appropriateness, $F(1, 18) = 64.9$, $p < .001$, and also an interaction between population and target appropriateness, $F(1, 18) = 29.78$, $p < .001$. As is evident in Fig. 1, although AD patients were sensitive to the appropriateness of the visual target, they were much less so than NCs. This finding supports the claim that AD patients have difficulty in maintaining active representation during discourse comprehension.

Correlations with MMSE, semantic, and working memory impairment. To evaluate the alternative hypotheses concerning AD patients' difficulty in maintaining active representation in memory, we looked for correlations between individual participants' sensitivity to pronoun appropriateness, as indicated by the difference between their mean pronoun naming latency in the appropriate and inappropriate conditions, and MMSE, picture naming, and month ordering scores. Because of the age and education differences between the two groups in this experiment, we controlled for these factors: The correlations of sensitivity to pronoun appropriateness with the different measures that are reported below are partial correlations after factoring out age and education. MMSE was not significantly correlated with sensitivity to pronoun appropriateness, Pearson $r(16) = .21$, $p < .2$. Picture naming was weakly correlated with sensitivity to pronoun appropriateness, and this correlation was only marginally significant, $r(16) = .37$, $p < .07$. Finally, month ordering was significantly correlated with sensitivity to pronoun appropriateness, $r(16) = .5$, $p < .02$. To clarify the role of picture naming and of month ordering separately, we tested for partial correlation between participants' sensitivity to pronoun appropriateness and either picture naming or month ordering, while controlling for the other measure (in addition to age and education). The correlation between sensitivity to pronoun appropriateness and month ordering was still significant, even when picture naming was controlled for, $r(15) = .45$, $p < .04$. In contrast, controlling for month ordering score eliminated the correlation between sensitivity to pronoun appropriateness and picture naming, $r(15) = .29$, $p < .13$. Thus, only month ordering correlated with sensitivity to pronoun appropriateness independently of the other measures.

As in the previous experiment, we wanted to ensure that the MMSE and picture naming measures did not contain too much or too little variance to allow them to yield significant correlations with sensitivity to pronoun appropriateness. To this end, we tested the correlations between MMSE, picture naming, and month ordering, while controlling for age and education. Indeed, these analyses revealed that MMSE correlated with picture naming, $r(16) = .47$, $p < .03$, and month ordering, $r(16) = .54$, $p < .01$. Picture naming did not correlate with month ordering, $r(16) = .24$, $p < .16$. The fact that MMSE and picture naming correlated indicates that both measures were sufficiently variable yet not too variable to allow the detection of correlations. Therefore, we conclude that participants' ability to maintain active

representation of information is strongly linked to their performance in the month ordering task, but not to their performance in the picture naming task, or to their MMSE score.

Discussion

Two basic findings in this experiment support the working memory impairment hypothesis. First, the AD patients had an impairment in pronoun comprehension evidenced by their reduced sensitivity, compared to NCs, to differences between appropriate and inappropriate pronouns. Second, the degree to which they were sensitive to the appropriateness of the pronoun correlated with our measure of working memory. Clearly, a working memory impairment reduces patients' ability to maintain an active representation of information necessary for processing pronouns.

Given the widespread use of pronouns in discourse, an impairment in processing this common type of referential expression could have serious consequences for comprehension of entire discourses. For example, failure to establish that *he* is coreferential with *John* and not *Bill* in ''John saw Bill at the party. He talked to him for a couple of minutes and then left'' would result in confusion about which person had left the party. In many cases, using a more explicit referring expression, such as a full NP, may help avoid such problems. Experiment 3 investigates how the choice of referring expression (pronoun vs full NP) affects AD patients' and NCs' abilities to comprehend discourse.

EXPERIMENT 3: PRONOUN AND FULL NPs IN COMPREHENSION

Perhaps the most commonly made observation about the use of reference is that there seems to be an inverse relation between the relative activation of the referent in working memory and the informativeness of the referential expression most likely to be used—the more active the referent is in memory, the less likely it is to be referred to by a highly informative expression, such as a definite NP (e.g., Almor, in press; Ariel, 1990; Chafe, 1976; Gundel et al., 1993; Prince, 1978; Valduvi, 1993). Indeed, less informative expressions like pronouns and null anaphors are almost exclusively used when the referent is very active in working memory (Ariel, 1990; Gundel et al., 1993). A recent theory developed in order to explain this inverse activation–informativeness relation is the Informational Load Hypothesis (ILH; Almor, in press). This theory associates cost and function with the processing and use of anaphoric expressions and states that any imposition of processing cost on the comprehender must serve some discourse function (identifying the referent and/or adding new information.) The ILH defines the comprehender's processing cost in terms of the semantic distance between the representation evoked by the anaphor and the representation of the antecedent—the less specific the representation evoked by the anaphor with respect to the

representation of the antecedent, the less costly the anaphor is to process. For example, given the antecedent ''a dog,'' the anaphor ''the little poodle'' would be more costly than the anaphor ''the dog,'' which in turn would be more costly than the anaphor ''the animal,'' which in turn would be more costly than the pronoun ''it.''

In this view, full NPs and pronouns create different demands during discourse comprehension. Although pronouns do not accrue much processing cost, their low informational content renders them less effective than full NPs as means of reactivating memory representation. In contrast, although full NPs have a higher processing cost than pronouns, they are better suited to reactivate information in working memory (Almor, in press), quite possibly because their lexical representations include many semantic features and thus provide an effective memory cue (Low & Roder, 1983).

Violating the cost–function balance principle of the ILH by using an anaphor that is not the best combination of cost and function leads to measurable comprehension difficulties in young healthy adults (Almor, in press; Gordon et al., 1993; Hudson & Tanenhaus, 1997). In particular, when a referent is highly activated in working memory, using a full NP to maintain reference impedes processing, while the use of a pronoun facilitates it (e.g., Gordon et al., 1993; Hudson & Tanenhaus, 1997). Based on these studies we expect elderly NCs to show better performance when pronouns rather than full NPs are used to maintain reference to active discourse entities.

However, when working memory is impaired, comprehension could be aided by expressions that are better in reactivating representations in working memory, even if these expressions are more costly to process. Thus, for AD patients, more explicit expressions like full NPs may be more functional than pronouns even when discourse context renders full NPs unnecessarily costly for NCs. Experiment 3 was designed to test this claim by examining the effect of the type of repeated reference on participants' ability to maintain active information in memory.

Method

Participants. The same participants as in Experiment 2 were tested in this experiment (see Table 3).

Materials and procedure. Items appeared in two conditions: pronoun and full NP. Items in all conditions started with an initial sentence that introduced two referents, one of which was modified with an adjective (e.g., ''The housewife watched the *clumsy* plumber working under the sink.''). Items in the pronoun condition used pronouns in the second and third sentences for repeated reference (e.g., ''*She* showed *him* where the leak was. *She* could not believe that *he* was so __.'') and items in the full NP condition used full NPs (''*The housewife* showed *the plumber* where the leak was. *The housewife* could not believe that *the plumber* was so __.'') The adjective *clumsy* was not repeated again in the auditory stimulus and was presented as the visual target at the end of the auditory fragment. Naming times to this target should provide an indication of how active the representation of the original modified referent (''clumsy plumber'') was at the probe. Overall, the experiment had two factors—Population

TABLE 4
Sample Item in Experiment 3 (Visual Targets in ALL CAPS)

Full NP condition
The housewife watched the clumsy plumber working under the sink.
The housewife showed the plumber where the leak was.
The housewife could not believe that the plumber was so CLUMSY.

Pronoun condition
The housewife watched the clumsy plumber working under the sink.
She showed him where the leak was.
She could not believe that he was so CLUMSY.

(AD, NC) and Reference Type (pronoun, full NP). Table 4 shows a sample item in both reference type conditions. If pronoun use facilitates processing for NC participants, they should exhibit shorter responses in the pronoun condition than in the full NP condition. However, because of the poor pronoun comprehension exhibited by AD patients in Experiment 2, and because of the working memory impairment of these patients, we expected them to show the opposite effect, namely better comprehension in the full NP condition than in the pronoun condition.

The cross-modal naming paradigm used in this experiment was identical to the procedure of Experiment 2. In the present experiment, latencies of reading the target adjectives in the two reference conditions (pronoun vs full NP) were used to indicate whether participants were able to maintain a memory representation of the information from the initial sentence in the different conditions.

Results

Naming latencies. As in Experiment 2, naming latencies were analyzed after eliminating all machine and reading errors (6.6% of responses) and latencies beyond 3 standard deviations from a participant's mean naming latency in a each session (further 1% of the data). Data were then normalized by transforming them into z scores based on each participant's mean and standard deviation in each session and further trimmed to exclude all responses that were more than 2.5 standard deviation above or below each conditions' mean (an additional 4.7% of the data). This further trimming was performed in order to address the variability introduced by the use of different target words in each item. The resulting adjective naming latencies are shown in Figure 2.

A 2×2 ANCOVA, Population by Reference Type with Age and Education as covariates, found no main effects of population or reference type, F's < 1, but a significant interaction between these factors, $F(1, 18) = 6.72$, $p < .02$. In line with our predictions, NCs named the adjective faster in the pronoun condition than in the full NP condition, but AD patients were slower to name the adjective in the pronoun condition than in the full NP condition.

Correlations with MMSE, semantic, and working memory impairment. As in the previous experiments, we investigated which of the dementia severity, semantic performance, and working memory measures were linked to RTs
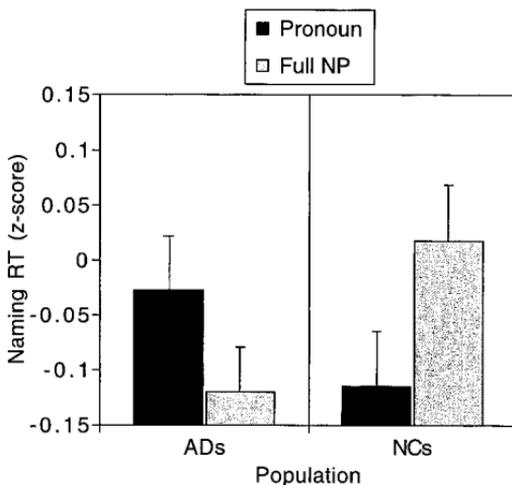
FIG. 2. Adjective naming latency in Experiment 3.

in this experiment. To that end, we calculated for each participant a pronoun advantage score by subtracting the participant's mean RT in the pronoun condition from his/her mean RT in the NP condition. Correlational analyses of the link between the pronoun advantage score and MMSE, picture naming, and month ordering, while controlling for age and education, yielded the following results. MMSE was marginally correlated with pronoun advantage, Pearson $r(16) = .35$, $p < .08$. The picture naming score did not correlate with pronoun advantage, $r(16) = .21$, $p < .21$. In contrast, month ordering correlated strongly with pronoun advantage, $r(16) = .68$, $p < .001$. To evaluate the individual contribution of month ordering and MMSE, we tested for the correlation between pronoun advantage and each of these factors while controlling for the other (in addition to age and education). Controlling for month ordering completely eliminated the correlation between pronoun advantage and MMSE, $r(15) = .03$, $p < .46$. However, controlling for MMSE did not eliminate the correlation between pronoun advantage and month ordering, $r(15) = .62$, $p < .004$. Thus, only month ordering independently correlated with pronoun advantage.

Discussion

Consistent with the ILH, the ability of AD patients to maintain active representation in working memory was substantially aided by the use of full NPs, while NCs were better served by the use of pronouns. This indicates that AD may alter the effects of discourse on the functionality of anaphors—discourse conditions which reduce the functionality of full NPs and thus render pronouns more felicitous than full NPs do not have the same effect on AD patients. These patients show better comprehension when full NPs are used regardless of discourse felicity. In line with the ILH's association

of anaphor functionality with the referent's activation in working memory, the benefit of full NPs correlated with working memory performance across all participants (but not with measures of dementia severity or semantic impairment). Thus, despite the extra processing required by full NPs, people with poor working memory performance show better ability to maintain active representation of information when full NPs are used.

GENERAL DISCUSSION

The research reported in this paper examined reference production and comprehension in AD patients. The major findings of this research were that although language production of AD patients is characterized by an abnormally frequent use of pronouns, their ability to comprehend pronouns is significantly compromised, and they are better able to maintain information about referents when full NPs are used. Furthermore, the tendency to prefer pronouns to other forms of reference in production (Experiment 1), the ability to maintain active representation in memory of information necessary for processing pronouns (Experiment 2), and the ability to use pronouns, as opposed to full NPs, to integrate items in the discourse (Experiment 3) all correlated with working memory performance. On the other hand, even though AD patients showed a marked semantic impairment, the degree of this semantic impairment showed no correlation with any other measure of reference processing. Similarly, overall dementia severity, gauged by the MMSE, did not correlate with any of the pronoun processing measures in this study. Overall, these data provide strong support for the working memory impairment hypothesis for both reference comprehension and production in AD patients. The fact that there was no link between semantic impairment and pronoun comprehension casts serious doubt on the viability of the semantic impairment hypothesis. Working memory performance but not semantic long-term memory performance is associated with referential deficits in AD.

One additional concern about the working memory hypothesis needs to be addressed. The fact that pronouns were ''preferred'' by AD patients in production but led to impaired processing in their comprehension may suggest a separate impairment in reference production and in reference comprehension. However, the global and patchy nature of the brain atrophy associated with AD (Terry et al., 1991), as well as the global cognitive impairment in AD, preclude an explanation based on selective and independent deficits to the comprehension and production systems. Rather, the nature of the brain and cognitive impairment in AD suggests that some general factor underlies both the reference production and the reference comprehension impairments. Indeed, the data show that verbal working memory performance, which by most accounts is a general factor (Carpenter et al., 1994; Daneman & Carpenter, 1980; Just & Carpenter, 1992; Just, Carpenter, & Keller, 1996; MacDon-

ald & Christiansen, 1998; MacDonald et al., 1992; Miyake, Carpenter, & Just, 1994; but see Waters & Caplan, 1996, 1997), is related to pronoun processing in production and comprehension.

Memory or Discourse Impairment?

As noted in the introduction, previous studies have suggested that AD patients may have not only a semantic impairment but also pragmatic discourse impairments (Andersen, Gonnerman, & Blakemore, 1996) and that these discourse impairments underlie referential problems in AD (Hutchinson & Jensen, 1980; Obler, de Santi, & Goldberger, 1995; Ripich & Terrell, 1988; Ulatowska et al., 1988; Ulatowska & Chapman, 1995). Given these claims, it is important to inquire whether the present findings reflect an impairment to an underlying discourse mechanism, namely an inability to produce and expect pronouns when discourse pragmatic principles dictate that they should be used, or whether they reflect the normal working of discourse mechanisms in the presence of a working memory impairment.

As discussed in conjunction with Experiment 3, reference comprehension impairments in AD are readily explained by the ILH (Almor, in press) on the basis of the same cost–function principles that explain unimpaired reference comprehension. The working memory impairment in AD leads to an overall decrease in the activation of referents, therefore enabling costly referring expressions (full NPs vs. pronouns) to attain more functionality for AD patients than for NCs. Thus, reference comprehension impairments in AD do not implicate a discourse-pragmatic specific impairment but only reflect the working memory impairment associated with the disease.

The ILH also applies to AD patients' reference production impairments. Because AD patients have a working memory impairment, their representation of referents in working memory is degraded, leading to the loss of some distinguishing semantic features (e.g., Martin, 1987; Tippett, McAuliffe, & Farah, 1995). For example, the representation of ''dog'' might become more similar to the representation of ''animal.''[3] According to the ILH, this loss of specific information about the referent causes an increase in the processing cost of all expressions referring to that referent. This is because the ILH defines cost on the basis of the semantic relation between the representations of the anaphor and the referent and not on the basis of the anaphor representation alone. For example, although the expression ''the animal'' has only little processing cost with respect to the referent ''the dog,'' it has a higher processing cost with respect to the referent ''the animal'' (because of the

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[3] Although AD patients make both superordinate (e.g., saying ''animal'' instead of ''dog'') and contrast coordinate errors (e.g., saying ''cat'' instead of ''dog''), both types of errors can be explained by specific feature loss (e.g., Tippett et al., 1995): if a distinctive feature (e.g., ''barks'') is lost, a patient may randomly select other names that match the remaining semantic features (i.e., both ''cat'' and ''animal'' match the remaining feature ''domestic pet'').

greater amount of *repeatedly* activated semantic features in the latter case than in the former). Therefore, when, because of a working memory impairment, semantic detail is lost in a referent's representation, a more general and less costly expression, such as a pronoun, is likely to be produced.

In summary, the present findings do not imply any special discourse pragmatic impairment in AD. In fact, AD patients' reference processing, much like young adults' reference processing, follows the same principles of cost and function. When cost or function changes, as they do for AD patients, the processing of referential expressions changes accordingly.

Empty Speech in Other Clinical Populations

Alzheimer's patients are not the only patients who produce empty speech. The speech of patients with fluent anomic and Wernicke's aphasia is also often uninformative. Nicholas et al. (1985) suggested that there is a continuum of speech informativeness with normals at one (informative) end, followed by anomic, Alzheimer's, and Wernicke's patients, in increasing degrees of emptiness. Previous work with aphasic patients has suggested that empty speech in aphasia is due to lexical semantic deficits. For example, Liederman, Kohn, Wolf, and Goodglass (1983) found that Wernicke aphasics were more likely than Broca aphasics and normal controls to use uninformative novel words in place of words they could not find; normal controls and Broca aphasics used novel but informative words when they had a difficulty finding the right word. Liederman et al. therefore suggested that the seemingly fluent but semantically empty speech of Wernicke aphasics was linked to a lexical deficit. Berndt, Sloan, Haendiges, Mitchum, and Sandson (1997) more recently argued that a lexical semantic deficit (but specifically with respect to verbs) leads to an overuse of empty speech in aphasic patients. Although the data presented here from AD patients shows that a working memory deficit can also result in empty speech, it is not clear that the working memory hypothesis applies equally well to aphasia. First, there is little known about verbal working memory function in fluent (particularly Wernicke's) aphasia, probably due to the difficulty in administering verbal working memory tests that require verbal responses (e.g., reading and listening span). Second, because Wernicke aphasics and AD patients produce very different types of paraphasias (Wernicke's frequently produce neologisms and literal paraphasias, while AD patients produce primarily semantic paraphasias), the empty speech in these two populations may be caused by different underlying conditions. Further research comparing the language and memory impairments of AD and aphasic patients would be valuable to determining the source of empty speech across diagnostic groups.

Clinical Implications

The present findings also have clinical implications. First, our results offer empirical support for advice commonly given to those communicating with

AD patients. Rau (1993) has suggested that in order to assist verbal comprehension in AD, caregivers should adjust their vocabulary and use ''concrete, specific and simple'' words (Rau, 1993, p. 77). Consonant with our finding that AD patients have considerable comprehension difficulty when reference is maintained through pronouns, Rau specifically suggests that caregivers avoid words such as ''this,'' ''these,'' ''he,'' and ''she.'' Our research indicates that these recommendations are appropriate and are likely to enhance patients' comprehension.

Fortunately, this advice may not be hard to follow. There is some evidence that, when addressing their AD patient spouse, caregivers increase their lexical redundancy (i.e., repeat relevant words, etc.) (Kemper, Anagnopoulos, Lyons, & Heberlein, 1994). This is especially interesting because regular ''elderspeak,'' namely speech that is directed toward older persons, although marked by shorter and syntactically simpler utterances than regular speech, does not include the type of increased lexical redundancy that we are proposing here and that Kemper et al. (1994) found. Thus, it seems that spouses of demented patients ''learn'' to make these specific modifications from their extensive interaction with their demented spouse. However, caregivers that are less intimately involved with AD patients (e.g., medical and day care staff and visitors) might need to be instructed to use specific and informative expressions even when these expressions seem redundant and unnatural. What may seem unnatural to most speakers may be an effective means for facilitating the comprehension of a person with a working memory impairment.

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