Journal of Speech and Hearing Research, Volume 30, 343–350, September 1987

SYNTACTIC PRESERVATION IN ALZHEIMER'S DISEASE

DANIEL KEMPLER SUSAN CURTISS CATHERINE JACKSON
University of California at Los Angeles

Language ability of 20 patients with probable Alzheimer's disease (AD) was evaluated. Analysis of spontaneous speech revealed a normal range and frequency of syntactic constructions but poor lexical use. A writing task showed a similar divergence, with the ability to use syntactic cues significantly more intact than the ability to use semantic cues. The results are taken to indicate that syntactic ability is selectively preserved in AD. These findings are consistent with a modular theory of grammar and of mental functions more generally. A tentative explanation of these phenomena is proposed in which the overlearned and automatic nature of syntactic ability helps account for its resilience to cognitive dissolution and cortical degeneration.

Recent research on adult language breakdown has addressed the issue of the potential independence of syntactic processes from semantic functions primarily by investigating the extent to which syntax appears to be impaired selectively in classical syndromes of focal aphasia. Broca's aphasia has been described as "agrammatism," a syndrome which impairs an individual's ability to use nonlexical grammatical markers and perhaps other syntactic devices to comprehend and produce language structures in controlled tasks (e.g., Grodzinsky, 1984b; Kean, 1985; Kolk, 1978; Zurif & Caramazza, 1976). The same impairment usually leaves intact the patient's ability to use lexical semantic information in the same tasks (Caplan, 1981, 1983). These data have been interpreted as lending empirical support to the argument for the existence of a highly specialized syntactic module or processor (e.g., Caramazza & Berndt, 1982).

If this interpretation is correct, then it should be possible for language breakdown to affect the linguistic system in an opposite fashion, that is, by leaving syntactic ability intact while impairing lexical functions. Several studies of language impairment in populations with nonfocal disease, particularly Alzheimer's disease, report this language profile. Whitaker (1976) studied a patient with presenile dementia who was restricted to echolalic output. The patient spontaneously corrected phonological, morphological, and syntactic anomalies in sentences presented to her but did not correct semantic anomalies. Schwartz, Marin, and Saffran (1979) studied a single Alzheimer patient who, despite severely impaired lexical knowledge, demonstrated intact grammatical comprehension of four semantically reversible syntactic forms in addition to well-formed grammatical production on a task requiring the manipulation of several syntactic structures. Irigaray (1973), perhaps the first to study a group of dementing patients with attention directed to their language abilities, demonstrated that those patients with language impairments were indeed more impaired in semantic and pragmatic realms than in phonological or morphosyntactic areas. Appel, Kertesz, and Fisman (1982) administered the Western Aphasia Battery (Kertesz, 1980) to categorize 25 Alzheimer patients into classical aphasic syndromes. Results indicated that transcortical sensory and Wernicke's type aphasias were frequent, while Broca's and transcortical motor aphasia were absent. Further investigation of subtest scores reiterated previous findings: the patients were impaired in lexical semantic and cognitive operations, but showed preserved phonological and syntactic abilities. Bayles (1979; 1982), in an attempt to identify the most useful language tests for the differential diagnosis of Alzheimer's disease, compared performance on linguistic tests (naming, sentence judgments, sentence correction, lexical and sentence disambiguation, story retelling and verbal description) with performance on psychological tasks generally used in diagnosis of the disease (e.g., WAIS block design, mental status questions). She reports that sentence correction (or more precisely, failure to detect and correct semantic errors) was the most sensitive of all the tests used.

The studies summarized above all converge on a similar conclusion: Syntactic ability is preserved in the context of impaired semantic ability in the dementing individuals studied. However, the extent to which preserved syntactic ability has been demonstrated in these studies is not clear. Several methodological problems must be addressed before definitive conclusions can be reached.

Some of the more convincing data have come from an experiment in which a patient spontaneously corrected morphological and syntactic but not semantic anomalies in a sentence repetition format (Whitaker, 1976). While these results lend support to the notion of an *independent* syntactic "filter" which can operate in the absence of semantic processing, the data may be open to other interpretations. The syntactic and semantic stimuli are not parallel, and it is unlikely that semantic and syntactic filters operate in a similar fashion. First, a semantic interpretation filter may operate largely on sentence-external contexts, while a grammatical filter must operate on single sentences since grammatical errors are largely determined by sentence-internal constraints. Perhaps a sentence repetition task triggers a grammatical filter but does not trigger an intact semantic filter. Second, the grammatical errors included on these tasks are usually "small" (e.g., person/number disagreement), in English often involving single phonemes, while semantic errors

  0022-4685/87/3003-0343$01.00/0

typically involve larger units (words). It is possible that in a repetition task an error minor enough to be considered a misperception would be corrected, but the rest would be repeated verbatim. In this way, the difference between the phonological size of syntactic and semantic errors in the stimuli may help explain the correction of only syntactic errors. The data afforded by the sentence repetition tasks may then be evidence for a grammatical filter but not necessarily for its dissociation from a semantic filter.

Additionally, many of the data are not based on linguistic evaluation as much as on standardized measures which do not assess syntactic ability at all. Appel et al. (1982) report frequency of aphasia type and aphasic symptoms in Alzheimer's disease, concluding that the presence of transcortical sensory aphasia and Wernicke's aphasia supports the hypothesis that this population demonstrates selectively preserved syntactic function. The structure of the Western Aphasia Battery (WAB), however, is such that these categories or diagnostic groups are based largely on assessment of "fluency" and "comprehension." Fluency is evaluated on rather subjective grounds during a conversation and picture description, and the comprehension measures do not systematically assess comprehension of syntactic structure abstracted away from lexical and real-world knowledge. In sum, few of the studies have taken care to use semantic and syntactic tasks of comparable difficulty, nor have they provided analyses of syntax and lexical semantic ability on the same task.

The research presented here was designed to overcome these methodological shortcomings and investigate the claims of the preservation of syntactic ability and the dissociation between syntactic and lexical semantic ability in patients with probable Alzheimer's disease. We examined syntactic and lexical semantic ability within two language production contexts in a carefully diagnosed group of patients. Our predictions were that if the syntactic preservation phenomenon is real, when task features such as attention, stimulus complexity, response complexity, and stimulus length are controlled for, we should observe relatively preserved syntactic ability in contrast to impaired lexical semantic performance within and across tasks.

SUBJECTS

The subjects were individuals diagnosed as having probable Alzheimer's disease (AD) by physicians at the UCLA Geriatric Outpatient Clinic or the Neurobehavioral Unit of the West Los Angeles Veterans Administration Hospital. Following current practice and diagnostic criteria (Cummings & Benson, 1983; McKhann et al., 1984), both exclusionary and inclusionary criteria were used. Each patient had a thorough physical examination, neurological examination, neuropsychological evaluation, laboratory evaluation (including complete urinalysis, CBC, thyroid function tests, serologic tests for syphilis, calcium, folate, SMAC panel, and vitamin B12 levels), EEG, EKG, chest X-ray, and CT of the head. Prior to diagnosis, non-Alzheimer pathologies (e.g., cerebral infarct, prior head trauma, infectious processes, drug or alcohol abuse, history of psychiatric problems) were ruled out. For all patients, the diagnostic evaluation documented a range of cognitive dysfunctions and an absence of focal motor, sensory, cerebellar, and cranial nerve defects. The diagnoses were made with the use of complete neuropsychological and neurological evaluation.

All subjects were monolingual, native English speakers, who were schooled in Standard American English and used Standard American English in their homes and work. None of the subjects had any known speech or language pathology prior to the diagnosis of AD. Age ranged from 62 to 87 years ($M = 75$; $SD = 5.8$). Education ranged from 8th grade to college. Performance on the Mini Mental Status Exam (Folstein, Folstein, & McHugh, 1975) ranged from 2 to 26 (of a possible 30). Testing generally took place in one session during the initial phase of the diagnostic evaluation. Twenty education- and gender-matched normally aging persons were included as controls (12 women, 8 men); their ages ranged from 64 to 84 years ($M = 73$; $SD = 5.3$). The data for the first investigation were drawn from a subgroup of 10 AD subjects and 10 age- and gender-matched controls for whom good tape recordings of spontaneous conversation were available. Each subgroup consisted of 6 men and 4 women. The age range for the AD subgroup was 62 to 84 ($M = 74$; $SD = 8.2$). The age range for the normal control subgroup was 62 to 84 ($M = 75$; $SD = 6.1$). The Mental Status scores in the AD group ranged from 2 to 26. All 20 AD and 20 control subjects participated in the second investigation.

To evaluate syntactic and semantic competence within the same tasks, we analyzed data from both a spontaneous speech sample and a controlled writing task.

INVESTIGATION 1: SPONTANEOUS SPEECH

Procedure

Because no extraneous test demands were placed on the subjects during spontaneous speech, conversation about familiar topics may display the subjects' optimal performance level. Therefore, to evaluate syntactic and lexical semantic performance in a relatively unconstrained circumstance, we analyzed 50 utterances of spontaneous conversation in 10 AD patients and 10 controls. Spontaneous language samples were drawn from interviews that were tape recorded and transcribed for analysis. Topics of conversation included family, profession, personal history, and questions from a neuropsychological interview. A minimum of 50 utterances was obtained from each patient. Fifty contiguous utterances were analyzed, excluding repetitions of self or examiner (as in questions of confirmation), sentences containing more than one unintelligible word, and formulaic utterances ("I don't know," "Oh, Lord"). The analyses involved a tally of all observed errors in

TABLE 1. Nine syntactic constructions counted in spontaneous speech.

Structure	*Example*
1. Simple sentence	"I was just talking."
2. Conjoined sentences	"They're interesting and they're nice."
	"I could drive even, but Celia won't. . . ."
3. Questions	"Did I have anything written there before?"
	"What do you want to know from me?"
4. Relative clauses	"These people that have money and time, they think that's fun."
	"They had a house that they sold."
5. Adverbial clauses	". . . instead of getting married before I was old enough."
	"I do it myself if I want to."
6. Infinitival clauses	"We wanted to take a little trip."
	"Did I give you the stuff to read?"
7. Passives/Topicalization	"This is handled by the whatchacallit."
	"It was in New York that they landed."
8. Complex comparatives	"I used to be a little smarter than I am (now)."
9. Other complements	"You've got a scheme for finding out what you want."
	"You tell me what you want them for."
	"And I said, 'Just leave me alone.' "
	"I think I'm spelling that right."

morphosyntax, including errors of constituent structure, noun and verb morphology, nonlexical grammatical markers, constituent movement, and errors in lexical use, including instances of lexical mischoice, empty forms such as "thing" and "do" without clear referents, and erroneous and unrecoverable anaphora.

In addition to errors in the two domains, we examined the range and frequency of syntactic constructions used. If syntax in production is preserved, we should see a normal range of simple and complex constructions, used with normal frequency. This is crucial because it is possible that AD patients achieve relatively error-free speech and observed fluency by relying on greatly reduced syntactic complexity or frequent production of a very few constructions. To gauge the range and frequency of correctly used syntactic structures, we examined the samples for the occurrence of constructions representative of the sentence structures of English syntax. These included simple sentences (i.e., single clause sentences), conjoined simple sentences, and 7 complex structures (e.g., sentences involving embedding or constituent movement). A list of these construction types, with examples from the transcripts is presented in Table 1.

Spontaneous speech samples were transcribed by one trained linguist and checked by another. All spontaneous speech transcripts were coded independently by two of the authors (one blind to subject group identification), and any disagreements were discussed and resolved. Intercoder reliability was computed separately for each aspect of the coding. For semantic errors in spontaneous speech, agreement averaged 87%; for syntactic errors in spontaneous speech, agreement was 95%.

Results

Two analyses of the spontaneous speech data are reported here: (a) error scores comparing syntactic versus lexical semantic errors and (b) range and frequency of constructions used, compared with normal age- and gender-matched controls.

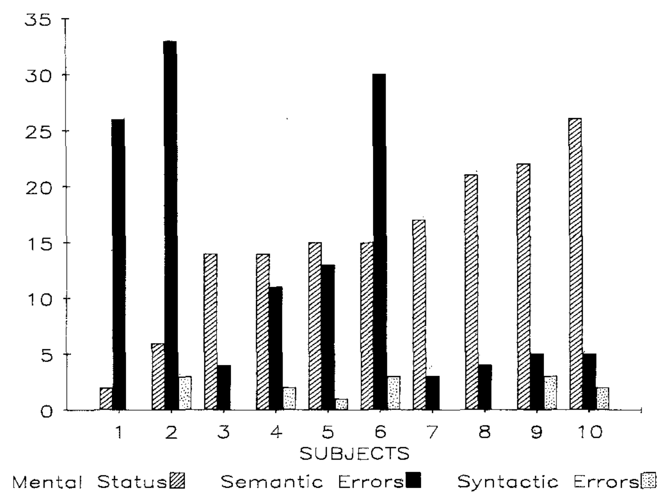

FIGURE 1. Number of semantic and syntactic errors in spontaneous conversations of 10 Alzheimer patients along with mental status scores.

Figure 1 is a graphic representation of the raw number of each type of error reported for each of the 10 AD subjects. The AD patients made significantly more lexical semantic than syntactic errors [$t(7) = 3.631$, $p < .005$]. It is notable that while the number of syntactic errors for the AD subjects ranged only from 0 to 3, with 4 of the subjects making no syntactic errors, there is considerably more variability in the number of semantic errors: all AD subjects made at least 3 semantic errors, but 3 subjects made more than 26 semantic errors.[1] This contrasts with

[1]Because 3 patients contrbuted a majority of the syntactic errors to the analysis, a separate t test compared the syntactic and semantic error rates for the other 7 subjects. The results confirm a significant difference between number of syntactic versus semantic errors for the group as a whole ($t = 4.583$, $p < .004$).

TABLE 2. Mean frequency of specific sentence structures observed in 50 utterances from each of 10 Alzheimer patients and 10 controls.

Alzheimer patients		*Controls*	
Construction	*Mean*	*Construction*	*Mean*
Simple sentences	23.3	Simple sentences	29.5
Other complements	8.3	Adverbial clauses	6.6
Adverbial clauses	7.3	Other complements	6.4
Conjunctions	6.0	Conjunctions	6.0
Relative clauses	2.9	Relative clauses	3.6
Infinitivals	2.5	Infinitivals	2.8
Questions	2.5	Questions	1.8
Complex comparatives	1.0	Passives/Topicalization	1.8
Passives/Topicalization	0.8	Complex comparatives	0.2

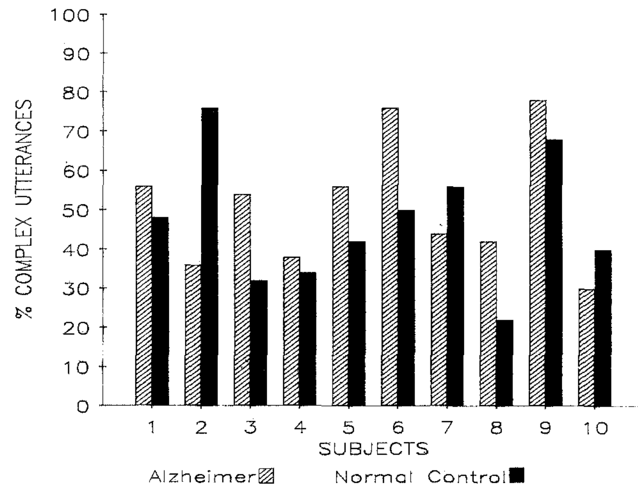

FIGURE 2. The percentage of complex utterances in Alzheimer patients' and normal controls' spontaneous speech. Alzheimer mean = 51%; range: 30%–78%. Normal control mean = 47%; range: 22%–76%.

the normal controls, 6 of whom made no errors of any kind, and who, in total, made only 6 errors (4 syntactic and 2 lexical semantic). The number of semantic errors made by the AD subjects appears to be correlated with overall severity of the disease as measured by the Mini Mental State [$r = .7057$; $p < .025$], while syntactic errors appear to be independent of overall severity, possibly due to the limited variance in the syntax error scores [$r = .1287$; $p > .05$].

Table 2 displays the frequency of sentence types observed in AD and control speech samples, rank ordered from most frequent to least frequent. The rank order of the constructions (ranked by mean frequency) was almost identical between the two groups ($\rho = .9833$; $p < .0000$). Thus, it appears that the two groups did not differ in the relative frequency of use of particular syntactic constructions.

To investigate the structural complexity of syntax in AD, we computed a complexity score for each of the 10 AD subjects and controls. This score is the percentage of utterances that contained some complex structure (any structure listed in Table 1 other than simple and conjoined sentences). Complexity percentages for the AD subjects and controls are given in Figure 2. No significant differences between the two groups were found [$t = -.664$; $p > .05$].

INVESTIGATION 2: WRITING TO DICTATION

Procedure

In a task adapted from Schwartz et al. (1979), all subjects were asked to write to dictation two-word phrases and word pairs. Each test item contained one member of a homophone pair together with either a syntactic or a semantic cue to disambiguate the spelling. Five pairs of homophones matched in frequency (Kucera & Francis, 1967) were presented, each one twice, once with a syntactic cue and once with a semantic cue (see Table 3). For example, the homophone pair *see* and *sea* was presented (a) with semantic cues ("look-see," "lake-sea") and (b) with syntactic cues ("I see," "the sea"). The subjects were told they would hear either a "short phrase" or "two related words" and that they should write down what they heard. All subjects were given 10 semantic-cue items followed by 10 syntactic-cue items. Items included in the analysis were those in which (a) the cue was accurately written, and (b) the patient attempted to write a homophone. In addition, if the two homophones in question were systematically distinguished (although perhaps misspelled as in *wrong-right; read-wright*), neither was counted as an error. All errors included in the analysis were the substitution of one homophone for another; most often it was the other homophone target, but occasionally the patients wrote unrelated homophones which were not intentionally elicited anywhere in the test (e.g., *wrong-rite; look-C*). The number of errors made with each type of cue was tabulated. In a more controlled context than spontaneous speech, this task allowed us to compare the subjects' ability to use syntactic and semantic knowledge for identical purposes: to disambiguate the spelling of a word.

TABLE 3. Homophones with syntactic and semantic cues.

Semantic cues	*Syntactic cues*
mouth-nose	my nose
thinks-knows	she knows
lake-sea	the sea
look-see	I see
read-write	I write
wrong-right	be right
day-hour	an hour
mine-our	our dog
spells-prints	she prints
king-prince	a prince

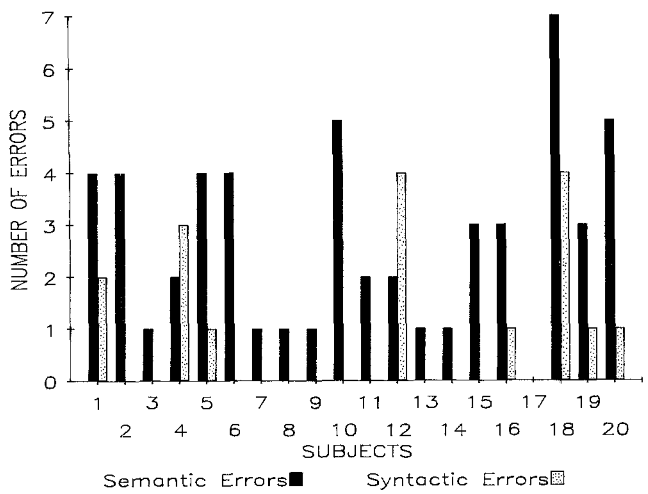

FIGURE 3. Numbers of errors made in the writing to dictation task with semantic cues versus syntactic cues for 20 Alzheimer patients.

Results

The 20 controls made three semantic errors and three syntactic errors as a group, with no individual making more than a single error. This indicates that the two cue conditions are roughly equivalent in overall degree of difficulty for a normal population. The number of errors made by the 20 AD subjects with both syntactic and semantic cue types was tabulated and is shown in Figure 3. A comparison of errors with each type of cue revealed a significant difference in the patients' ability to use the two types of cues in writing, with the ability to make use of syntactic cues significantly more preserved [$t(19) = 4.173$, $p < .001$]. These results demonstrate that in a task that directly compares the subjects' use of syntactic and semantic information for an identical purpose, the patients are significantly better able to use the syntactic information. The role of perseveration in these data is of some concern. Because the patients wrote each target twice and heard four stimuli that sounded identical, it is possible that some errors resulted from perseveration rather than from the inability to use a syntactic or semantic cue. To estimate the possible role of perseveration, the number of possible perseverative errors (i.e., errors which were the second, third, or fourth consecutive occurrence of any one spelling) was calculated. Thirty-one errors (44%) fell into this category (35% of the semantic errors and 71% of the syntactic errors). The remaining 56% of the errors were all the first occurrence of an accurately spelled but nontarget homophone. Because the semantic-cue items were given first, and many errors (31% of total errors, 41% of the semantic-cue errors) fell on the first five items, there is strong evidence that perseveration is not the major cause of errors. Even after subtracting possible perseverative errors, there remain 35 semantic-cue errors and 5 syntactic-cue errors, with still a significant difference [$t(19) = 5.090$, $p < .001$]. This suggests that no matter what nonspecific processing limitations affect these patients, they have significant difficulty making use of semantic cues in a spelling task.[2]

DISCUSSION

Our results demonstrate that across two different language production contexts, syntactic ability is significantly better preserved than lexical semantic ability in AD. Syntactic errors in spontaneous speech and writing were significantly fewer than lexical semantic errors in the same tasks. The high semantic error rate is likely due to an inability to use semantic knowledge rather than performance difficulties in the semantic (but not the syntactic) portion of the tasks. In addition, the hypothesis of preserved syntax is confirmed by a more detailed analysis of the spontaneous speech of a subgroup of these patients, which indicated that their speech output contains a similar range and frequency of syntactic constructions and an overall similar level of structural complexity to matched normal controls. These findings are relevant to models of language ability and neurolinguistic theories that attempt to specify the association between language and the brain. Each is discussed below.

Implications for Linguistic Theory

Models of language, like theories of mind more generally, can be divided into two rough categories: those that focus on the interaction and interdependence of various knowledge systems and those that highlight their modularity. The first approach is best exemplified by functionalist models that attribute syntactic structure to a combination of semantic and communicative principles (Bates & MacWhinney, 1982; Dik, 1978; Givón, 1979; Lakoff & Thompson, 1975), while the latter approach presumes that language knowledge is best characterized as a system of distinct, interacting but autonomous modules (e.g., Chomsky, 1981; Fodor, 1983). The relative status of syntax vis-a-vis other language modules (notably lexical semantics and pragmatics) has recently become a central point in discussions of the relative autonomy of mental systems in both the field of linguistics and cognitive science (e.g., Fodor, 1985).

Each of these approaches (explicitly or implicitly) makes different predictions about patterns of language dissolution. Therefore, the study of acquired adult language breakdown provides relevant evidence in this debate. Theories that stress the unity and interaction of different aspects of language predict that in cases of language breakdown we should see generalized linguis-

[2]Another issue of some concern in interpreting these data is the order of presentation. It is possible that, because semantic-cue items were always presented before syntactic-cue items, practice effect reduced the number of errors on the syntactic-cue items. However, considering the inability of the patients to learn and remember information over a short period of time, a practice effect is relatively unlikely to explain these data.

tic, communicative, and, possibly, intellectual impairment, but not syndromes reflecting impairments in distinct parts of the system. Arguments for such a position are found in the writings of, for example, Bay (1962), Darley (1982), Duffy and Duffy (1981), Goldstein (1948), and Schuell, Jenkins, and Jimenez-Pabon (1964), who maintain that adult aphasics suffer from a general symbolic deficit, and differ from each other primarily in severity of aphasia, not type.

By contrast, a modular theory predicts that selective impairments of any aspect of mental function, including distinct modules of language, should be possible. This model is supported by the work of Benson (1979), Geschwind (1965), Goodglass and Kaplan (1972), and others, who have documented many distinct aphasic syndromes, each one presumed to be due to a disruption of the neural substrate underlying one or more aspects of the linguistic system, and the work of Caplan (1981, 1983), Grodzinsky (1984a, 1984b), and Kean (1977), who have characterized specific aspects of aphasic breakdown as a deficit within a single module of the grammar.

If syntactic ability constitutes an independent module, it should be doubly dissociable from semantic knowledge in deficit conditions. Therefore, we would logically expect to see syndromes that selectively preserve syntax as well as those that selectively impair it. As mentioned earlier, a syndrome of selectively impaired syntactic ability ("agrammatism") has been described in detail over the past decade. However, the other side of the double dissociation has not been convincingly documented. Attempts to document preservation of syntax in focal aphasias have met with conflicting results. For instance, although some Wernicke's aphasics appear to produce a normal range of sentence structures (e.g., Goodglass & Kaplan, 1972) and retain the ability to use syntactic information in some structured tasks (Von Stockert & Bader, 1976), they appear to use a more restricted range of syntactic constructions in writing (Gleason et al., 1980), they do not appear to be normally influenced by major clause boundaries for the purposes of programing sentence intonation patterns (Danly & Cooper, 1983), and they appear to have a syntactic deficit on comprehension of semantically reversible sentences (Martin & Friederich, 1983). In this context, then, it becomes important to substantiate recent claims that individuals with AD, at least in the moderate and late stages, show relatively preserved syntactic abilities in the context of impaired lexical semantic abilities. The results presented here both support and extend past research on the pattern of language disolution in AD, demonstrating that the selective preservation of syntax is possible and occurs with some regularity in particular deficit conditions.

Implications for Neurolinguistic Theory

From the standpoint of linguistic theory, the dissociation between syntax and semantics makes sense, since they are generally considered distinct components or "modules" of the grammar. However, neurolinguistic theory must go beyond confirming that theoretically independent modules can be dissociated in a deficit condition. A full account of the linguistic profile associated with AD will include an explanation compatible with both the broader neuropsychological profile and, eventually, the underlying neuropathology of AD.

A partial explanation of the preservation of syntax might be found in the notion of automaticity and the neurology that might underly automatic behaviors. Automatic processes "operate independently of the subject's control . . . do not require attention . . . and they do not use up short-term capacity" (Schneider & Shiffrin, 1977, p. 51). In contrast, controlled processes "require attention . . . [and] use up short-term capacity" (p. 52). While automatic processes appear to develop where the range of alternatives is limited (i.e., consistent or frequent mapping between stimuli and responses), controlled processes are called upon when the range of alternatives is broad and unpredictable (i.e., varied mapping between stimuli and responses).

Syntax, phonology[3], and morphology, once acquired, can be characterized as automatic and mandatory: "You can't help hearing an utterance of a sentence (in a language you know) as an utterance of a sentence," (Fodor, 1983, p. 52–53). Lexical selection, on the other hand, can be characterized as a control process. Several features are important in distinguishing syntactic and lexical abilities. First, the range of alternatives in syntactic structure is relatively constrained (consistent mapping), particularly when compared with lexical choice, which involves selection from a broad array of possibilities (variable mapping). Second, each instance of a grammatical structure in a given language occurs relatively more frequently than individual (substantive) lexical items occur. In this formulation, syntax has the characteristics of high frequency and consistency; that is to say, characteristics of automatic or mandatory systems. These characteristics, we propose, are responsible for the preservation of syntax in AD.

One major qualification must be made before pursuing this argument further. Syntax is not automatic in some absolute sense, but is more automatic than such controlled processes as lexical selection. Within a general domain such as syntax, there is much variation in degree of automaticity, probably determined by relative frequency of forms and combinations. Some sequences are virtually unbreakable and frequently used without variation, for example, the days of the week, counting, social interaction formulas. On the other hand, there is a whole range of items that require integration of novel elements: Familiar sentence frames require the insertion of novel forms (e.g., "I'd rather be X-ing"), and all novel sentences require the insertion of lexical items into common (e.g., subject-verb-object) structures. In short, syntax is not completely automatic and does require integration of novel information for normal use.

[3]Although not addressed in this paper, phonological ability was observed to be intact as well.

If syntax is largely automatic (in the adult), and automatic processes are preserved in AD, we can make several predictions. We should expect maintenance of those aspects of grammatical production that do not require integration of novelty. Also, we should see errors in those instances that do require the integration of controlled processing. These predictions appear to be borne out. Automatic sequences (e.g., counting, the days of the week) are relatively well maintained until the late stages of the disease. This is also true for the construction of grammatical forms (e.g., surface subject-verb, word, constituent, and phrase order) in spontaneous speech. However, the controlled process of lexical selection (word choice) does not fare so well: Empty forms (e.g., "thing," "it," "do") render speech meaningless from the early stages of the disease.[4]

Automaticity has long been used to explain why certain skills are maintained in the case of brain damage. For example, Anton Pick (cited in Gardner, 1975) used automatization to account for exceptions to the rule that earlier acquired skills are better maintained in brain damage:

> Occasionally on an accidental basis, the greater automatization of later acquired functions provides an exception to the rule and shows that it is not age itself but rather its resultant *degree of automatization that determines the increased resistance* [italics added]. (p. 279)

According to Gardner (1975), skills developed to a high level during early life "may achieve an independent autonomous status, so that they can 'run off' or function smoothly even when the brain is otherwise deranged" (p. 279).

Although the notion of automaticity has been used to explain preservation of function (e.g., Craik, 1985; Jorm, 1986), to our knowledge, no specific theory of the underlying neurology of overlearned or automatic function has been offered. If automaticity is to be fully explanatory of the neuropsychological profile of AD, it must eventually be translated into neurological terms.

There are no accepted models that provide a neural basis for the dissociations of automatic and controlled processes. Nevertheless, one line of research appears particularly promising and is outlined here. The proposed model relies on several aspects of neural organization. The cortex consists of two distinct cytoarchitectural dimensions: the horizontal dimension, which is made up of the basal dendrites of the pyramidal cells, and the vertical dimension, which is made up of the apical dendrites of those same cells. The two systems (horizontal and vertical) are organized differently: The vertical dimension is modularized into vertically oriented columns, and, within each column, there are bundles that include the apical dendrites of the 20 to 30 cells. The horizontal circuitry, however, contains no obvious subunits and is marked by extensive overlapping. Theories of cortical memory (e.g., Anderson, 1977) and hemispheric asymmetry (e.g., Woodward, 1984) have used this distinction to explain various phenomena. For example, in Anderson's model, the response characteristics of the vertical circuitry are ideally suited for feature detection and such related phenomena as categorical perception (Anderson, Silverstein, Ritz, & Jones, 1977). The horizontal circuitry, in contrast, is particularly suited to recognition memory, which involves searching over a store of memories and requires a large number of simultaneous comparisons between new and old memory traces. Automatic processes, because they deal with overlearned material, undoubtedly rely on feature detection and might be mediated by the vertical circuitry. Controlled processes closely parallel recognition memory since they require comparisons across larger sets of data and may fit into horizontal cortical schema.

If this theory is to account for the data observed in AD, then we must posit that either the horizontal substrate is particularly vulnerable to the degeneration in AD, or the vertical substrate is particularly resiliant. Both viewpoints appear to have some support. The vertical modules have been reported to yield high resistance to cell loss in general (Roney, Scheibel, & Shaw, 1979; Shaw, Harth, & Scheibel, 1980), and the progressive degeneration of dendrites in AD appears to affect the horizontal dendritic branches first and most drastically (Cummings & Benson, 1983).

The speculative theory proposed here has at least two advantages. First, it accounts for the preservation of the syntactic abilities with a single, general construct (automaticity). Second, it suggests an anatomical basis for the types of linguistic degeneration and preservation that are observed in AD. Accounting for these patterns will necessarily move us closer to a neurolinguistic theory in which we can state precisely how language structure and function correspond to neurological structure and function.

[4]An interesting parallel to the preservation of automatic language functions is the preservation of overlearned motor functions. Fully automatic motor processes, such as speech articulation, getting out of bed, and walking are preserved until the late stages of the disease. It is when new information needs to be integrated that deficits appear: Moderate stage AD patients may start to cook and forget the stove is on; start the car, shift, maneuver out of the garage, and then get lost. Later in the course of the disease, although the automatic mechanics of dressing and walking are maintained, patients may overdress themselves (e.g., put on several shirts) or not be able to find their way around even familiar locations. As with syntax, the most frequent and most consistent motor patterns are maintained late in the disease, while integration of those patterns into novel situations is severely impaired.

ACKNOWLEDGMENTS

Parts of this research were presented at the Eighth Annual Boston University Conference on Language Development and in the first author's doctoral dissertation. This research was supported in part by National Science Foundation (Grant BNS 79-26659) and The San Diego Alzheimer Disease Research Center (NIA #P50-AG0-5131). We are grateful to the UCLA Geriatric Outpatient Clinic and the Neurobehavioral Unit of the West Los Angeles Veterans Administration Medical Center for patient referrals.

REFERENCES

ANDERSON, J. A. (1977). Neural models with cognitive implications. In D. L. LaBerge & S. J. Samuels (Eds.), *Basic processes in reading: Perception and comprehension* (pp. 27–90). Hillsdale, NJ: Lawrence Erlbaum.

ANDERSON, J. A., SILVERSTEIN, J. W., RITZ, S. A., & JONES, R. S. (1977). Distinctive features, categorical perception, and probability learning: Some implications of a neural model. *Psychological Review, 84,* 413–451.

APPEL, J., KERTESZ, A., & FISMAN, M. (1982). A study of language functioning in Alzheimer patients. *Brain and Language, 17,* 73–91.

BATES, E., & MACWHINNEY, B. (1982). Functionalist approaches to grammar. In E. Wanner & L. R. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 173–218). Cambridge, MA: Cambridge University Press.

BAY, E. (1962). Aphasia and non-verbal disorders of language. *Brain 85,* 411–426.

BAYLES, K. (1979). *Communication profiles in a geriatric population.* Unpublished doctoral dissertation, University of Arizona, Tucson.

BAYLES, K. (1982). Language function in senile dementia. *Brain and Language, 16,* 265–280.

BENSON, D. F. (1979). *Aphasia, apraxia and agraphia.* New York: Churchill/Livingston.

CAPLAN, D. (1981, March). *Syntactic competence in agrammatism, a lexical hypothesis.* Paper presented at Neuroscience Research Program, Boston, MA.

CAPLAN, D. (1983). A note on the word-order problem in agrammatism. *Brain and Language, 20,* 155–165.

CARAMAZZA, A., & BERNDT, R. S. (1982). Semantic and syntactic processes in aphasia: A review of the literature. *Psychological Bulletin, 84,* 898–918.

CHOMSKY, N. (1981). *Lectures on government and binding.* Dodrecht: Foris.

CRAIK, F. I. M. (1985). Age differences in remembering. In L. R. Squire & N. Butters (Eds.), *Neuropsychology of memory* (pp. 3–12). New York: Guilford Press.

CUMMINGS, J. L., & BENSON, D. F. (1983). *Dementia, A clinical approach.* Woburn, MA: Butterworth.

DANLY, M., & COOPER, W. E. (1983). Fundamental frequency, language processing, and linguistic structure in Wernicke's aphasia. *Brain and Language, 19,* 1–24.

DARLEY, F. (1982). *Aphasia.* Philadelphia: W. B. Saunders.

DIK, S. (1978). *Functional grammar.* New York: North Holland.

DUFFY, R. J., & DUFFY, J. R. (1981). Three studies of deficits in pantomimic expression and pantomimic recognition in aphasia. *Journal of Speech and Hearing Research, 46,* 70–84.

FODOR, J. (1983). *The modularity of mind, an essay on faculty psychology.* Cambridge, MA: MIT Press.

FODOR, J. (1985). Precis of the modularity of mind. *The Behavioral and Brain Sciences, 8,* 1–42.

FOLSTEIN, M. F., FOLSTEIN, S. E., & MCHUGH, P. R. (1975). Mini Mental State: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189–198.

GARDNER, H. (1975). *The shattered mind.* New York: Random House.

GESCHWIND, N. (1965). Disconnexion syndromes in animal and man. *Brain, 88,* 237–294, 585–644.

GIVÓN, T. (1979). *On understanding grammar.* New York: Academic Press.

GLEASON, J., GOODGLASS, H., OBLER, L., GREEN, E., ACKERMAN, N., HYDE, M. R., & WEINTRAUB, S. (1980). Narrative strategies of aphasic and normal-speaking subjects. *Journal of Speech and Hearing Research 23,* 370–382.

GOLDSTEIN, K. (1948). *Language and language disturbances.* New York: Grune & Stratton.

GOODGLASS, H., & KAPLAN, E. (1972). *The assessment of aphasia and related disorders.* Philadelphia: Lea & Febiger.

GRODZINSKY, J. (1984a). *Language deficits and linguistic theory.* Unpublished doctoral dissertation, Brandeis University, Waltham, MA.

GRODZINSKY, J. (1984b). The syntactic characterization of agrammatism. *Cognition, 16,* 99–120.

IRIGARAY, L. (1973). *Le langage des dements.* The Hague: Mouton.

JORM, A. F. (1986). Controlled and automatic information processing in senile dementia: A review. *Psychological Medicine, 16,* 77–88.

KEAN, M. L. (1977). The linguistic interpretation of aphasic syndromes. *Cognition, 5,* 9–46.

KEAN, M. L. (1985). *Agrammatism.* New York: Academic Press.

KERTESZ, A. (1980). *The Western Aphasia Battery.* London, Ontario: University of Western Ontario.

KOLK, H. (1978). The linguistic interpretation of Broca's aphasia. *Cognition, 6,* 353–361.

KUCERA, H., & FRANCIS, W. N. (1967). *Computational analysis of present day American English.* Providence: Brown University Press.

LAKOFF, G., & THOMPSON, H. (1975). Introducing cognitive grammar. *Papers of the First Annual Meeting of the Berkeley Linguistic Society,* 295–313.

MARTIN, R. C., & FRIEDERICH, F. (1983, October). *Syntactic deficits in fluent aphasics: Two case reports.* Paper presented at the Academy of Aphasia, Minneapolis, MN.

MCKHANN, G., DRACHMAN, D., FOLSTEIN, M., KATZMAN, R., PRICE, D., & STADLAN, E. M. (1984). Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease. *Neurology, 34,* 939–944.

RONEY, K. J., SCHEIBEL, A. B., & SHAW, G. L. (1979). Dendritic bundles: Survey of anatomical experiments and physiological theories. *Brain Research Reviews, 1,* 225–271.

SCHNEIDER, W., & SHIFFRIN, R. (1977). Controlled and automatic human information processing: I. Detection, search and attention. *Psychological Review, 84,* 1–66.

SCHUELL, H., JENKINS, J. J., & JIMENEZ-PABON, E. (1964). *Aphasia in adults: Diagnosis, prognosis and treatment.* New York: Harper.

SCHWARTZ, M., MARIN, O., & SAFFRAN, E. (1979). Dissociations of language function in dementia: A case study. *Brain and Language, 7,* 277–306.

SHAW, G. L., HARTH, E., & SCHEIBEL, A. B. (1980, November). *Cooperativity in brain function: Assemblies of 30 neurons.* Paper presented at the tenth annual meeting of the Society for Neuroscience, Cincinnati, OH.

VON STOCKERT, T. R., & BADER, L. (1976). Some relations of grammar and lexicon in aphasia. *Cortex, 12,* 49–60.

WOODWARD, S. (1984). An anatomical model of hemispheric asymmetry. Unpublished manuscript.

WHITAKER, H. (1976). A case of the isolation of the language function. In H. Whitaker & H. A. Whitaker (Eds.), *Studies in neurolinguistics, Vol. 2* (pp. 1–58). New York: Academic Press.

ZURIF, E. B., & CARAMAZZA, A. (1976). Psycholinguistic structures in aphasia: Studies in syntax and semantics. In H. Whitaker & H. A. Whitaker (Eds.), *Studies in neurolinguistics, Vol. 1* (pp. 261–292). New York: Academic Press.

Received August 25, 1986
Accepted January 13, 1987

Requests for reprints should be sent to Daniel Kempler, The Audiology and Speech Pathology Service (126), Veterans Administration Medical Center, 16111 Plummer Street, Sepulveda, CA 91343.