Effects of Semantic Impairment on Language Use in Alzheimer's Disease

Lori J. P. Altmann, Ph.D.,[1] and Jill S. McClung, M.S., CCC-SLP[2]

ABSTRACT

Many studies present apparently conflicting results and conclusions about the effects of Alzheimer's disease (AD) on language use. This review attempts to reconcile these apparently conflicting results regarding the language impairments in AD by discussing how the slow deterioration of the semantic system at the feature level interacts with the task demands of tests used to evaluate performance. In particular, performance is impaired on tasks that require relatively complete, elaborate semantic representations but is preserved when the task requires only partial semantic representations consisting largely of shared features. The variety of language impairments reported in complex, multiword tasks are likely attributable to a combination of the deterioration of semantic representations and reduced working memory resources. The few available treatment studies for language impairments in AD suggest that treatments designed for adults with other language impairments, such as aphasia, may also be effective in AD.

KEYWORDS: Alzheimer's disease, semantic impairment, semantic memory, language impairment, review

Learning Outcomes: As a result of this activity, the reader will be able to (1) discuss how Alzheimer's disease affects language performance in single-word tasks, (2) discuss how Alzheimer's disease affects language performance in sentence and discourse tasks, and (3) discuss how task demands interact can affect performance on typical assessment tasks such as picture naming, verbal fluency, and word-picture matching tasks.

As life expectancies continue to increase, so too does the prevalence of Alzheimer's disease (AD). AD is the most common type of dementing illness worldwide, afflicting more than 5 million people annually in the United States alone.[1] Although episodic memory decline (e.g., remembering recent events) is considered the hallmark symptom of the disease,

[1]Assistant Professor; [2]Department of Communication Sciences and Disorders, University of Florida, Gainesville, Florida.

Address for correspondence and reprint requests: Lori J. P. Altmann, Ph.D., Department of Communication Sciences and Disorders, University of Florida, Box 117420, 336 Dauer Hall, Gainesville, FL 32611-7420 (e-mail: laltmann@ufl.edu).

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language decline is also a significant early marker of the disease.[2,3] Individuals with AD typically live independently at least until the moderate stages of the disease.[4] Therefore, difficulties understanding language and producing coherent speech can have serious and potentially dangerous consequences, because understanding instructions and warnings, communicating wants and needs, remembering the answers to questions, and following directions may all be impaired relatively early in the course of the disease.

NEUROLOGY

Cognitive and language impairment in AD occur in a hierarchical progression based on the neurologic substrates affected. Although there is considerable variability in the distribution and progress of damage, a typical progression of the disease has been identified.[5] Initially, signs of the disease are evident in the entorhinal cortex and hippocampus, both of which are essential for the encoding of new memories. Consequently, deficits in the ability to remember recent events, learn new information, and recall information after a delay are characteristic of the disease. Therefore, tests of delayed recall appear in all memory screening tests for adults.

As the disease progresses, damage spreads to adjacent cortical structures, such as the inferior temporal lobe, the temporo-occipital junction, and the temporoparietal junction.[5,6] Impairments in these regions often lead to loss of knowledge about words and their underlying concepts.[7,8] Thus, researchers have suggested that semantic representations crucial for meaningful language are located in these regions (see Antonucci and Reilly,[9] this issue). Furthermore, the temporoparietal region is strongly interconnected with the dorsolateral prefrontal cortex, which is essential for working memory and executive function[10]; thus, atrophy in this area also impairs the ability to recruit frontal lobe resources for language and cognition. Working memory deficits, therefore, arise early in AD and have pervasive effects on the ability to produce and comprehend complex language.

Subtypes of AD exist because the spread of the disease can vary across individuals. For example, disease pathology occasionally takes a slightly more posterior route, affecting the occipitoparietal region, resulting in disproportionate difficulty with visual perception and spatial cognition (i.e., visual variant AD).[11] Also occasionally, the neurologic damage of AD manifests in the perisylvian region and mimics progressive nonfluent aphasia. For example, Croot et al[12] described 10 individuals with AD pathology who demonstrated nonfluent speech, false starts, and phonologic paraphasias, as well as the semantic paraphasias, word omissions, and verbal perseverations characteristic of AD. Thus, as in aphasia, the behavioral manifestations of AD depend crucially on the location and extent of cortical damage.

SEMANTIC THEORY

Most contemporary views hold that semantic representations consist of multitudes of component features (i.e., aspects of meaning) that are interconnected into a complex network that encodes everything a person knows about a concept.[13,14] Semantic features are conceptualized as analogues of neurons that follow similar principles; thus, when two features are active at the same time, a connection between them is formed, and the more frequently two features are used simultaneously, the stronger the connection between them becomes. Importantly, semantic features are often shared by the representations of many different words, particularly words within the same category.[14,15] For example, semantic representations of most mammals likely include the features, *has legs, has ears,* and *has fur*; thus, these features will be strongly interconnected because they co-occur in many words.[16,17] Shared features and the connections between them help to give structure to semantic categories.[15,16,18] Besides shared features, the semantic representation of words also include distinguishing features that differentiate between related items within a category. For example, the two features, *has a mane* and *has stripes,* differentiate "lion" and "tiger." By definition then, distinguishing features are connected to the semantic networks of only a few words.[14,19]

Maintaining the analogy between semantic features and neurons, AD has been hypothesized to affect semantic representations similar to the way it affects neurons, with the weakening of connections between features occurring first, followed by the loss of individual features.[20] Because features that are used frequently and the connections between them are more robust, shared features are more resilient than are distinguishing features in AD.[21,22] An inability to activate distinguishing features might cause semantic paraphasias, the substitution of a related word for a target, the production of a superordinate term such as a category name (e.g., calling a squirrel an "animal"), or a complete inability to name an item.[21,23] Progressive loss of distinguishing features can lead to ambiguous semantic representations consisting primarily of sets of shared features, which can potentially refer to a range of related items.

Related to this pattern of loss is the finding that individuals with AD have often been reported with specific impairments affecting categories of living things compared with man-made things.[20,21] To account for this, many studies have demonstrated that the semantic representations of living things have a smaller proportion of distinguishing features, whereas those of man-made things have a majority of distinguishing features.[15–17,20–22] Consequently, when distinguishing features of living things are lost, only the shared features of a word may be available, leading to semantic errors. In contrast, losing the same number of distinguishing features in the representation of a man-made object will still leave some distinguishing features present to help identify the item.[21] Our discussion of the effects of AD on language performance relies heavily on this model of semantic memory and these hypotheses regarding the effects of AD pathology on the semantic system.

SINGLE-WORD PROCESSING

Word production in AD is usually assessed with picture naming, naming to definition, or category fluency tasks, all of which show evidence of anomia. Anomia is one of the most common manifestations of early AD.[1] The majority of language studies on AD have focused on, or at least included, deficits in single-word production elicited by picture naming, which increase in severity as the disease progresses.[23–25] Picture naming studies have examined the relative influences of visual perception, semantic deficits, and stimulus characteristics (e.g., semantic category, frequency, familiarity, word class). Although visual perceptual impairments in AD may contribute to difficulties with picture naming,[26,27] most researchers have concluded that errors stem primarily from lexical-semantic degradation rather than from visual-perceptual deficits.[28–30]

Most studies examining semantic memory in AD have tested performance with concrete nouns and have concluded that a progressive deterioration of semantic memory leads to early semantic feature loss and impairs higher-level category information only later in the disease.[21,23,31] Martin and Fedio[3] tested this theory using single-word comprehension, picture naming, and word fluency and demonstrated that knowledge about specific items (i.e., distinguishing features) was lost early in the disease, whereas superordinate category knowledge remained better preserved. The most common picture naming errors in very mild AD are semantic paraphasias, or within-semantic-category substitutions (e.g., "lion" for tiger or "airplane" for helicopter).[23,32] Gonnerman and colleagues documented the progression of picture naming errors over time, demonstrating that, as severity increases, errors evolved from typical semantic paraphasias (e.g., "lion" for tiger) to superordinate errors (e.g., "animal" for tiger) to "I don't know" responses.[23] Another common error type is circumlocution (e.g., "it lives in the jungle and it's very dangerous"); however, these errors may be more common in other types of dementia than in AD.[33] Similar error types are also found when individuals with AD try to name pictures of famous people.[34] This pattern is consistent with the above theory that AD first impairs lower-frequency, distinguishing semantic features, then, as the severity of the impairment increases, shared features also become impaired. This pattern was illustrated in a longitudinal study of semantic impairment in AD, in which Garrard and colleagues[21] compared the performance of individuals with AD at two time points in two tasks: picture naming and semantic feature generation. Individuals with AD produced fewer distinctive features than shared features overall, and this was exaggerated for items they could not name. Thus, this study demonstrated a direct correspondence between having knowledge about an item and being able to name it; furthermore, it provided strong evidence for the gradual loss of distinguishing features preceding the loss of shared features.

Researchers have also found verbal fluency tasks to be a valuable tool in the differential diagnosis of AD from other dementias.[35] There are two types of fluency tasks: semantic and phonemic. Semantic fluency (e.g., name as many animals as possible in a minute) is thought to tap both semantic knowledge and executive function. In contrast, phonemic fluency (e.g., name as many words as possible beginning with letter F in a minute) is thought to require a controlled search through the lexicon and, thus, rely more on executive function and less on semantic knowledge. Several studies have determined that individuals with AD were significantly more impaired on semantic fluency and picture naming than on phonemic fluency, and some have argued that the impairment on fluency tasks is more severe than that affecting picture naming.[35,36]

Psycholinguistic research has demonstrated that characteristics of stimuli, such as imageability, word frequency, prototypicality, and category membership, influence performance on a variety of language tasks. Silveri and colleagues[37] showed that individuals with AD named pictures more accurately when words were acquired earlier in life (i.e., age of acquisition effects), were from nonliving categories as opposed to living things categories, and had only one possible name (e.g., "table" vs. sofa/couch/davenport, a name agreement effect). However, they found no effects of word frequency, prototypicality, familiarity, or word length. In contrast, in a large, multisite study of category fluency (e.g., "name as many animals as you can in one minute"), Sailor et al[38] showed that individuals with AD accessed words more slowly overall than did control subjects and also showed an effect of typicality on production: Relative to controls, individuals with AD produced similar numbers of typical items (e.g., "dog") but significantly fewer atypical items (e.g., "giraffe"). Thus, in AD, typicality within a category had no effects on picture naming but was associated with the ability to generate words within a category.

Although single-word *production* has been found to be unambiguously impaired in AD, the results from other tasks are not so clear-cut. The typical profile of performance in AD includes impaired picture naming, category fluency, and naming to definition, with relatively preserved word-picture matching, category sorting, and semantic priming.[39] This pattern of performance led to one of the most vigorously debated issues early in the study of language in AD: whether the disease impaired access to intact semantic representations or damaged the actual stored representations themselves.[40,41] Both Nebes et al[42,43] and Ober et al[44,45] argued that knowledge of semantic attributes was preserved in AD based on finding intact semantic priming from words and sentences. On the other hand, Chertkow et al[46] argued for deterioration of semantic knowledge, because in their study individuals with AD consistently made errors on the same items across tasks. Furthermore, Henderson and colleagues[25] reported that items that caused occasional difficulties for individuals with AD early in the disease were completely inaccessible later. Researchers in the latter two studies suggested that small amounts of damage could lead to inconsistent errors on particular items early in the disease, but as the disease progressed, the representations of these items became fully degraded, and the word was no longer available to the speaker. To resolve this issue, several researchers have suggested that these conflicting results might stem from differences in task demands.

Ober[39] reviewed the performance of individuals with AD in numerous semantic studies, contrasting performance on semantic priming and other tasks like picture naming and judgment tasks. Semantic priming requires participants to read a target word or name a target picture after presentation of a related or unrelated prime word. In normal speakers, targets following a related prime are produced faster than targets following an unrelated prime.[44,47] This effect is usually attributed to either the spread of activation along the connections within the semantic network[48] or to feature overlap between the prime and target word.[16] Ober concluded that task demands had a strong influence on the performance of individuals with AD. In particular, performance on tasks like semantic priming or category verification that relied on "automatic" processes, such as spreading activation within the semantic network or overlapping semantic features, was preserved in AD; whereas, "controlled" processes that relied on the ability to search semantic memory and discriminate between related items, such as picture naming, were impaired. Similarly, Cuetos and colleagues[49] argued that task demands might influence performance on semantic tasks in AD. They examined performance of 20 individuals with AD across 17 tasks. They concluded that performance on tasks requiring semantic access (i.e., spoken and written picture naming, verbal fluency) was impaired, whereas performance on tasks testing phonologic access (i.e., lexical decision, word repetition) was relatively preserved. Thus, in AD performance on tasks that rely primarily on automatic processes, spreading activation or feature overlap within the semantic system or on phonologic access is preserved, but performance on tasks requiring a semantic search or judgment is impaired.

Further evidence for deficits in controlled semantic processing in AD comes from tasks such as similarity judgments and board sorting. Grossman and Mickanin[26] found that individuals with AD were more impaired at verifying that *pictures* showed examples of a VEGETABLE than verifying that the printed *words* for the same items referred to a VEGETABLE. In addition, the AD group was extremely impaired when foil pictures or words were FRUITS, a highly related category. Grossman and Mickanin attributed these findings to a specific difficulty activating semantic representations from pictures, as well as difficulty discriminating between items in closely related categories such as fruits and vegetables. Grossman and colleagues[50] and Smith and colleagues[51] identified significant declines in the ability to verify semantic features of items, particularly distinguishing features of atypical category items (e.g., "does a penguin swim?"). Smith et al attributed these findings to a degradation of knowledge that particularly affected distinguishing features of atypical items from various categories. Taking a different approach, Chan et al[52] showed that individuals with AD and control subjects used the same general factors for making relatedness judgments (e.g., size, domesticity, and predation) using a similarity judgment task (e.g., which two of these three animals are most alike?). However, as dementia severity increased, the judgments of individuals with AD became progressively more random. These findings are consistent with AD causing a progressive loss of semantic features, which initially affects distinguishing features and ultimately also impairs shared features.

Other studies have compared performance of individuals with and without AD on tests with different levels of task demands. For example, Aronoff and colleagues[53] examined the performance of individuals with AD on picture naming and a board-sorting task (e.g., "put these words on this board so that items that are similar are closer together"). They found that individuals with AD tend to cluster items more closely together than do healthy subjects, and that this was particularly true in categories with many naming errors. They concluded that these results were consistent with a progressive loss of features and connections among semantic features, leading to individuals with AD perceiving more apparent similarity among category items than do normal participants. Giffard et al[54] also addressed this question by comparing performance on direct probes of semantic attribute knowledge requiring explicit, controlled search of semantic memory (e.g., "Tell me about tigers"), as well as on semantic priming of related word pairs (i.e., lion-tiger) and attribute word pairs (zebra-stripe), using the same stimuli across tasks. Individuals with impaired performance on semantic probes showed abnormally large priming effects, or hyperpriming, in the related pairs priming condition but not in the attribute priming condition. The authors attributed hyperpriming to degradation of the distinguishing features within the semantic system, which caused the semantic representations of related items (e.g., lion and tiger) to become nearly identical; thus, the prime-target sequence activated the same set of semantic features twice.

Converging evidence that AD leads to a degradation of distinguishing features comes from studies using electroencephalography (EEG) that examine individuals with AD during semantic tasks. Castañeda and colleagues[55] used a category verification task to examine the way the brains of individuals responded to trials in which the stimulus item belonged to the target category (e.g., Is an ostrich a BIRD?) or did not belong to the target category (e.g., Is a giraffe a BIRD?). They demonstrated that the brains of people with AD reacted similarly (in speed and magnitude of response) to those of control subjects when a stimulus item belonged to the target category, but when the stimulus item and category did not match, their cortical reactions were slower and less intense, resulting in hyperpriming. Because tasks like semantic priming and category verification depend on existing connections in the semantic system (at least theoretically), relatively normal performance when prime and target or stimulus and category are semantically related supports the assertion that in early AD, semantic networks maintain their overall structure, even while slowly deteriorating because of disease processes.[42,45,48]

All of these studies present strong evidence that AD attacks semantic representations at the feature level, with distinguishing features being most vulnerable. This leads to semantic representations consisting of a disproportionate number of shared features, which results in ambiguous semantic representations that are difficult to distinguish from each other when activated. This process has different effects depending on the task. First, performance on tasks that rely on access of phonologic information but not semantic memory is preserved until quite late in the disease. Furthermore, performance is relatively preserved on less demanding tasks that can be accomplished based on overlapping features or the spread of activation (e.g., semantic priming, category sorting) or by the elimination of alternatives based on a minimal quantity of available distinguishing features (e.g., word-picture matching). However, tasks that require more precise activation (e.g., picture naming, naming to definition) or the generation of information about items (e.g., semantic knowledge probes and definitions tasks) show impaired performance early in the disease. Similarly, performance on tasks that require a controlled search through memory, such as category fluency tasks, are also severely impaired early in the disease. Over time, the damage becomes more severe so that only category information may be activated for production. However, evidence suggests that at least partial comprehension of words (e.g., general category information) may be preserved until quite late in the disease,[11,56] perhaps due to the resilience of shared features.

SENTENCE AND DISCOURSE PROCESSING

There is considerable evidence from the normal sentence processing literature, and somewhat less from sentence production literature, that sentence comprehension and production both require working memory.[57–59] As stated above, working memory is impaired in AD early in the disease because of loss of neural connections between posterior language areas and frontal regions that support working memory. Consequently, impairments in the production and comprehension of sentences and longer discourse would be expected and indeed have been found in early AD.

Spontaneous speech in mild-moderate AD is usually described as being preserved, because phonology, syntax, and turn taking appear to be intact, although information content is reduced relative to normal age-matched speakers.[60–62] Semantic paraphasias affecting open class words (i.e., nouns, verbs) are relatively frequent, whereas morphology and syntax are specifically described as being preserved.[2] Difficulties with pronoun use, manifesting as substitutions, omissions, or lack of referents, have also been widely reported in AD speech and can lead to difficulties for the listener.[24,62,63] Studies of oral descriptions of pictures and videos have found decreases in use of open class words,[64] sentence complexity,[65] and information content.[61] Interestingly, Cuetos et al[66] reported similar reductions in information content and noun use in the picture descriptions of individuals with mild cognitive impairment, often a preclinical form of AD,[67] suggesting that these characteristics of language output manifest very early in the disease.

Reports of spared morphology and syntax in AD[2] led to early conclusions that language production was characterized only by impaired content. However, in a study of conversational speech in AD, Altmann and colleagues[24] found that individuals with mild-moderate AD produced more errors than did their healthy peers in open class words (i.e., nouns, verbs, adjectives) and pronouns, as expected, but also found more errors in closed class words (i.e., determiners, auxiliary verbs, prepositions, conjunctions) and morphosyntax (e.g., verb tense errors, verb argument structure errors, missing matrix clauses). Furthermore, Altmann et al found error rates in spontaneous speech correlated with picture naming scores, suggesting that the same deficit, semantic impairment, was underlying both types of difficulty. However, Kavé and Levy[68] disputed this, having found preserved use of grammatical morphology in Hebrew speakers with AD. These authors suggested that their findings were inconsistent with those of Altmann et al due either to differences in the method of elicitation (i.e., spontaneous conversation in Altmann et al vs. picture description in their study) or differences in the experimenters' error coding systems. Another possibility not raised by Kavé and Levy is that differences in the morphologic structure of the two languages, English and Hebrew, may have contributed to the discrepant findings. Thus, preservation of grammatical morphology in AD is an open question whose answer may vary cross-linguistically.

Few experimental studies of sentence production in AD have been reported. Altmann[69] tested the ability of individuals with AD to generate sentences that included three words (e.g., a name, a common noun, and a verb) printed on a card. Individuals with AD had severe difficulties with the task. They were extremely dysfluent, made many grammatical errors, and often omitted stimulus words from their responses, although the words remained visible throughout a response. Altmann concluded that the difficulties were due to having to activate and combine the meanings of several words at once, as well as not having the option of using empty speech when they could not access a word meaning. These findings suggest that impairments in language production extend beyond the single-word level in AD.

Sentence comprehension is also impaired in AD, and the basis of this impairment has been attributed to both semantic[51,70] and working memory dysfunction,[71–73] as well as the interactions of these impairments with task demands.[71,73] Consistent with our initial analysis of the effects of AD pathology on language use, the preponderance of evidence has shown that, at least in early stages, sentence comprehension difficulties likely result from deterioration of semantic and working memory rather than from a purely syntactic impairment. For example, Grossman and Rhee[29] found that individuals with AD were sensitive to syntactic violations in sentences, but they showed only marginal sensitivity to semantic violations. These authors attributed their findings to pathologic slowing of information processing that was likely due to semantic impairment but asserted that there was no specific loss of syntactic knowledge.

Waters et al[73] examined sentence comprehension in a series of sentence-picture matching experiments comparing the effects of different types of presentation (e.g., video, two-picture arrays, three-picture arrays, single-picture verification) and different types of foils (e.g., semantic vs. syntactic). They found that performance on arrays with three pictures was worse than on arrays with two pictures or in single-picture verification (e.g., "Does this picture fit the sentence, 'It was the duck that swam across the pond'"). In addition, performance with stimuli that included three actors and two verbs, referred to as two-proposition sentences in these studies (e.g., "The horse kicked the elephant that touched the dog"), was impaired regardless of task. Similar findings were reported by Rochon et al.[74] In a sentence-picture matching task with two-picture arrays, individuals with AD were significantly impaired compared with control subjects on two-proposition sentences, and performance on these sentences correlated with working memory scores. Thus, these studies suggested that, in AD, task demands and the amount of information in a sentence can interact with working memory impairments to limit performance on sentence comprehension.

Kempler and colleagues further investigated the underlying causes of language comprehension deficits in AD and similarly highlighted the pivotal effects that task demands can have on the performance of this population.[71,72] They contrasted performance in an online comprehension task, which used reading times to tap sentence processing as it actually happened, to performance in an offline comprehension task, which required an untimed judgment.[75] In a simple off-line auditory sentence-picture matching task employing a range of syntactic structures, individuals with AD performed poorly, and their performance on this task correlated with working memory scores. However, a second experiment using the same individuals compared off-line grammaticality judgments with performance on a cross-modal sentence processing task. Sentences were presented aurally, followed by orthographic targets that were either grammatical or ungrammatical continuations of the sentence. Individuals with AD showed similar grammaticality effects as control subjects but were impaired on the off-line grammaticality judgment task. Furthermore, scores on grammaticality judgment and sentence-picture matching correlated with working memory scores. These results demonstrated that the way in which sentence comprehension is tested is of the utmost importance; only when comprehension was tested overtly, requiring the comprehension and integration of all words and syntactic cues, did individuals with AD exhibit impaired comprehension of auditory sentences, and then the degree of impairment was related to working memory deficits.

Almor and colleagues examined semantic and working memory components of pronoun comprehension in sentences using a similar cross-modal methodology to measure grammaticality effects associated with pronouns.[76] Sentences were presented aurally, followed by orthographic targets that were either appropriate or inappropriate pronouns to complete the sentence. Individuals with AD were less sensitive to pronoun errors than were controls and remembered less information from paragraphs in which information was mentioned as a pronoun as opposed to a noun. Moreover, performance correlated with working memory but not semantic impairment. A second study by Almor and colleagues investigated the sensitivity to pronoun and verb agreement errors on individuals with AD in longer, more complex material.[77] Almor et al reported that sensitivity to pronoun number agreement across sentence boundaries was impaired, but sensitivity to subject-verb agreement errors that occurred within a sentence was not impaired. In addition, only performance on the pronoun number agreement task correlated with working memory scores. The authors argued that maintaining information across sentence boundaries made great demands on working memory and was impaired in AD.

Discourse comprehension studies in AD have shown that the modality of information presentation affected performance. For example, individuals with AD answered yes-no questions about discourse presented using video tapes and demonstrated impaired comprehension, although they were more likely to retain the main idea than they were to retain specific story details.[78] Participants also were able to understand explicitly stated material more accurately than material requiring inference. However, Chapman and colleagues found that individuals with preclinical and early AD failed to process both the details of narratives and its gist.[79] The task that they used, however, required subjects to read a story while the experimenter simultaneously read it aloud to them. Thus, participants were required to process language in two modalities at once, making it more difficult because of the need for recruitment of multiple cognitive resources. In support of this idea, Mahendra and colleagues[80] examined immediate and delayed memory in a story-retell task. Stories were presented in three conditions: experimenter reading aloud, participant reading silently, and participant reading silently while the experimenter read the story aloud. Although their delayed memory was impaired regardless of presentation modality, individuals with AD exhibited the greatest immediate retention of the material when they had silently read it.

In summary, sentence and discourse production and comprehension in mild AD are significantly impaired, and that impairment is exacerbated in more demanding situations, such as when the meaning of a sentence must be established exactly in sentence-picture matching tasks or story retelling, or when the words for use in a sentence were not chosen by the speaker. Thus, a diagnosis of impaired or preserved language production and impairment in AD depends crucially on the tasks used for assessment.

THERAPEUTIC INTERVENTIONS

Individuals with AD are being diagnosed at ever earlier stages of the disease, highlighting the need for evidence-based treatments to help preserve and protect cognitive and linguistic function as the disease progresses.[81] However, the literature on cognitive and linguistic interventions for individuals with AD is relatively sparse due to a pervasive belief that cognitive decline is inevitable and, thus, a waste of time and resources. This belief is changing slowly. Several behavioral techniques have demonstrated promising results in improving aspects of cognitive function in individuals with AD, but only a few have targeted language use. Interventions that have shown significant effects on language use include errorless learning,[82–85] spaced retrieval training,[86–89] and language-based training (Morelli[90]; Ousett et al[91]). These studies, in general, have been well-designed but have had small sample sizes or small training sets. Treatments have demonstrated, in general, treatment effects for trained items, occasionally maintenance of those effects, but little evidence of generalization.

Errorless learning is a theory-based approach that focuses on reinforcing the strength of accurate connections with the system and minimizing the chance for creating incorrect connections.[92] Errors are kept to a minimum during training by minimizing guesses (i.e., encouraging "I don't know" responses instead) and using extensive repetition to strengthen connections between a stimulus and a response. Gonzalez Rothi and colleagues[86,87] treated anomia in AD using errorless picture-naming tasks in four sessions per week that incorporated systematically reduced clinician support across trials and extensive repetition of target words until criteria were met. Three of the six subjects demonstrated significantly improved naming of trained but not untrained items, as well as maintenance of effects in all three patients three months posttreatment. These findings suggest that picture naming impairments in some individuals with AD may be remediable using extensive repetition and errorless approaches to treatment.

Spaced retrieval is a technique incorporating errorless learning and repetition into memory enhancement tasks using an expanding interval schedule of practice; for example, the clinician waits for longer and longer intervals before probing the target item.[89–91,93] The goal of spaced retrieval is to capitalize on intact paired-associate learning in AD, rather than to strengthen semantic networks, and has resulted in improved naming of common objects,[94] as well as maintenance for at least 2 weeks.[89,95] However, these interventions have often focused on recognition or recall of only a small number of words or pieces of information[90,91,93]; thus, their usefulness for more extensive remediation is questionable.

Direct "lexical therapy" has also been used to target naming in a treatment study by Ousset and colleagues.[91] The treatment was provided weekly over a 5-month period to a group of individuals with mild AD and compared the effects on picture naming performance of the addition of a narrative context to a naming-to-definition task. Narratives were read by participants and then to participants and included several of the words that were trained using naming-to-definition. The authors reported significant naming improvements for those who heard the words in context in addition to the training but not for those who only had the naming-to-definition training. Furthermore, only treated items improved significantly. The most effective cues when an item could not be named were found to be initial phonemes and color drawings, rather than semantic or contextual cues. The authors suggested that the anomia in AD was a result of impaired access to lexical phonology with simultaneous damage to the connections between the object representation and the word. However, an alternate interpretation would suggest that phonologic and color picture cues provide more useful information to disambiguate competing word representations when distinguishing features are impaired.

In a recent extension of previous work, Arkin and colleagues[96,97] tested the effects of repeated exposure and effortful information retrieval processing on performance on a category fluency task. Training exercises included picture naming and answering semantically relevant questions about types of clothing. After 8 weeks of training, the overall number of exemplars generated in semantic category fluency task increased significantly. Interestingly, participants produced several of the trained items and showed generalization by producing untrained category members throughout the experiment. The authors pointed out that the study provided evidence of both explicit semantic learning (e.g., increased production of trained items) as well as implicit learning, shown by the production of untrained category items. Thus, this type of training may have increased the accessibility of shared features underlying several category members leading to generally improved category fluency in this category. In a follow-up study, Mahendra et al[97] replicated the study using items from the category "animals." The training component consisted of naming pictures and completing semantically related study questions targeting sensory, functional, behavioral, and culturally familiar attributes, accompanied by clinician feedback. After eight weekly sessions, participants showed the same pattern as when clothing was trained.[96] However, consistent with previous reports of category-specific impairments for natural categories like animals,[21,23] participants trained with clothing improved more than those trained with animals. These findings are consistent with those of Morelli[90] who stated that interventions that focus on rebuilding the connections within a category of words by semantic training and word repetition can improve lexical access in individuals with mild AD.

Morelli tested an adaptation of an aphasia treatment (see Kiran and Thompson, in review)[98] to see whether a semantic treatment would facilitate lexical access in individuals with AD. This study tested the effects of using repetition plus a semantic-feature training on picture naming of typical and atypical category members. In one 2-hour session, each participant named items from three categories, transportation, clothing and tools; then received semantic training on a subset of typical items from one category (e.g., car, bus, and bicycle from TRANSPORTATION) and atypical items from another category (e.g., tape measure, T-square, and sawhorse from TOOLS), leaving the third category untrained. There were overall effects of task repetition: participants were significantly faster and more accurate at posttest in all categories including the untrained one. Importantly, trained items were named significantly more accurately and marginally faster at posttest than were items from the untrained category. Moreover, untrained typical items from the category trained with typical items improved also, showing generalization of training. The author argued that stimulating the connections within semantic representations by combining semantic feature training and repetition of items from within a semantic category strengthened the connections within word representations, facilitating access not only to trained words but also to words that shared semantic features with the trained words.

These studies demonstrate that remediation of anomia in AD is possible using techniques adapted from other populations, such as aphasia. Clearly, however, more work is needed to determine how best to remediate the underlying deficits. Most approaches have tried to capitalize on procedural learning[83,89,91,93]; however, significant improvements have been minimal using this approach (e.g., in Ousset et al,[91] mean improvement on naming was six items after 5 weeks of treatment). The use of repetition plus semantic training by Morelli et al represents a different approach by explicitly training the aspect of language that is most impaired by the disease. These approaches are very different, and it remains to be seen which will prove the most effective method for remediating language difficulties in AD.

CONCLUSION

In this review, we have presented a model of how aspects of the neuropathology of AD affect the language system. In this model, semantic features and connections between features are vulnerable to disease-related impairments, and this vulnerability is mediated by frequency of use. Semantic features and connections that are used more often due to their presence in the representations of many related items (i.e., shared features) are more robust in the face of damage, because frequency of use has increased their strength.[14,19,21] In contrast, features and connections that are used more seldom, because they are relevant to only a few items (i.e., distinguishing features), are at risk for loss due to lower-strength connections at onset. Thus, as the disease progresses and lower-frequency, distinguishing features are lost, the semantic representations of a word become gradually more underspecified, leading to semantic representations that are ambiguous and potentially refer to several related items.[21,23] This process interacts with the task demands of the tests used to examine semantic deficits.[39] Performance is impaired on tests requiring a relatively complete, unambiguous semantic representation for success, such as picture naming or naming to definition. In contrast, performance is preserved on tests that can be accomplished using a minimal set of distinctive features, such as word-picture matching, or those requiring only shared features, such as semantic priming and category verification. Furthermore, semantic deficits interact with working memory limitations to impair the production and comprehension of sentences and discourse. Consequently, the ability to express wants and needs accurately and unambiguously is impaired, as is the ability to interpret connected language correctly. Thus, it is our contention that the full spectrum of language impairments in AD can be explained by the combination of progressive semantic and working memory impairments accompanied by loss of the ability to encode new memories, all of which are consistent with findings regarding the distribution of damage within the cerebral cortex.

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