Facts, Events, and Inflection: When Language and Memory Dissociate

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Abstract

■ We report on two brain-damaged patients who show contrasting patterns of deficits in memory and language functioning. One patient (AW) suffers from a lexical retrieval deficit and failed to produce many irregularly inflected words such as *spun*, *forgotten*, and *mice*, but demonstrated intact production of regularly inflected words such as *walked* and *rats*. She also had preserved declarative memory for facts and events. The other patient (VP) presented with a severe declarative memory deficit but showed no signs of impairment in producing either regular or irregular inflections. These patterns of deficits reveal that the retrieval of irregular inflections proceeds relatively autonomously with respect to declarative memory. We interpret these deficits with reference to three current theories of lexical structure: (a) Pinker's "words and rules" account, which assumes distinct mechanisms for processing regular and irregular inflections and proposes that lexical and semantic processing are subserved by distinct but interacting cognitive systems; (b) Ullman's "declarative/procedural" model, which assumes that mechanisms for the retrieval of irregular inflections are part of declarative memory; (c) Joanisse and Seidenberg's connectionist model, in which semantic information is critical for the retrieval of irregular inflections. ■

INTRODUCTION

Neuropsychologists have repeatedly observed that language and memory can be affected in a variety of ways by acquired brain damage. Although in some patients only certain aspects of either language or memory functioning appear to be impaired (e.g., speaking vs. reading; long-term memory vs. short-term memory [STM]), in other patients language and memory are both damaged, sometimes with different degrees of severity (for review, see Andrewes, 2001; Shallice, 1988). These observations lead to two very general conclusions about language and memory processing. First, both language and memory consist of clusters of partially separable processes, and neither is an undifferentiated cognitive system. Second, the brain structures that support language and memory do not overlap completely—if this were the case, one would expect the co-occurrence of language and memory deficits of equal severity to be the norm. If findings seem to rule out the hypothesis of completely overlapping systems for language and memory, it remains possible that at least some of the components of language and memory share common brain structures.

In the present article, we examine the relationship between the *lexicon*, which stores linguistic knowledge about familiar words, and *declarative memory*, which stores knowledge about facts and events. We examine three contrasting theoretical approaches to language processing: (1) the words and rules account, originally proposed by Pinker (1991), and adopted by many other researchers (e.g., Marcus, 2000; Clahsen, 1999; Marslen-Wilson & Tyler, 1998); (2) the declarative/procedural model of Ullman (2001a, 2001b); and (3) a connectionist model proposed by Joanisse and Seidenberg (1999). We consider whether each of these accounts is able to explain the pattern of lexical and declarative memory deficits of two neurologically impaired patients, AW and VP, who present contrasting patterns of associations and dissociations that suggest that lexical and declarative memory processes are neurologically distinct. We outline the common and contrasting assumptions of the three theories and what predictions they make vis-à-vis the association and dissociation of deficits in language and memory.

Words and Rules Account

There is a broad class of psycholinguistic models that subscribe to the assumptions of the "words and rules" (W&R) or "dual model" account (e.g., Marcus, 2000; Clahsen, 1999; Pinker, 1999; Marslen-Wilson & Tyler, 1998). These models share the assumption that words are either stored within the lexicon or are assembled through combinatorial operations on morphemes, commonly referred to as applying the "rules of language." Operations that imply rule application are called

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"regular." According to this approach, regular inflectional processes such as applying the *–s* to *chair* to make *chairs*, or the *–ed* to *walk* to make *walked* require only the stems, *chair* and *walk*, to be represented in the lexicon. Irregularly inflected forms like *ran*, *took*, or *mice*, on the other hand, must be stored in the lexicon as wholes.

Processing requirements for accessing stored lexical items must differ considerably from those demanded by combinatorial assembly. By hypothesis, these two types of processes should be expected to recruit distinct brain areas for their operation. In line with this hypothesis, proponents of the W&R account have amassed an impressive body of results that show systematic differences between regularly and irregularly inflected forms in terms of their acquisition and processing (for recent reviews, see Marcus, 2000; Pinker, 1999). In addition, selective problems with either regular or irregular inflections have been reported in brain-damaged patients affected by different neuropathologies. Such findings, reviewed below, suggest that distinctions between regular and irregular inflections have a neuroanatomical basis.

Within the traditional W&R framework, there exists a further assumption regarding the autonomy of lexical and semantic systems. In the case of inflections, the determination of whether a particular form takes a regular or irregular inflection is claimed to be independent of semantic properties of words. The lexicon is assumed to contain three kinds of information about words: (a) syntactic (e.g., that *photo* is a noun, singular), (b) phonological (e.g., that the onset of *photo* is /f/), and (c) orthographic (e.g., that the onset letter of *photo* is *p*). The semantic system, on the other hand, contains information about the meanings of words and perhaps other conceptual knowledge. Naturally, the lexicon and the semantic system must interact. Most obviously, lexical items must trigger semantic processing in language comprehension, and semantic knowledge must induce the selection of specific lexical items in language production. Similar interactions must also occur between the semantic system and combinatorial mechanisms so that the meanings of morphologically complex words are interpreted and produced in appropriate contexts. Despite these interactions, various aspects of lexical processing unfold independently of semantics, according to the W&R account: The lexicon and the semantic systems are in different "boxes" in the model, and interact only peripherally (see Pinker, 1999, p. 23).

Evidence that lexical, combinatorial, and semantic processing are supported by distinct but interacting brain regions would provide strong support for the W&R assumption that these types of processing are independent. One kind of evidence that could adjudicate this case would come from neuropsychological patients with selective deficits for lexical, combinatorial, or semantic processing. Such evidence will be considered in the case studies reported in this article.

The Declarative Procedural Model

The declarative procedural (DP) model, recently proposed by Ullman (2001a, 2001b), has its roots in the W&R account: It shares the assumption that lexical and combinatorial processes are functionally and neuroanatomically distinct. However, Ullman breaks with the traditional W&R account in suggesting that the distinction between stored and computed representations in language is a reflection of the more pervasive distinction between declarative and procedural memory. Declarative memory has been viewed as a system devoted to learning and remembering facts (semantic knowledge) and events (episodic knowledge), whereas procedural memory is implicated in the learning and processing of skills that require sequencing of mental representations or motor activities (Squire & Zola, 1996; Schacter & Tulving, 1994). Ullman (2001a) goes further and proposes that "the declarative memory system underlies the mental lexicon, whereas the procedural system subserves aspects of mental grammar" (p. 718; see also Pinker & Ullman, 2002). Declarative memory is viewed as an "associative memory that stores not only facts and events, but also lexical knowledge, including the sounds and meaning of words," whereas procedural memory "subserves the implicit learning and use of a symbol-manipulating grammar across subdomains that include syntax, morphology and possibly phonology." According to this hypothesis, regularly inflected forms like *walked* and *rats* are products of combinatorial processes and so require procedural memory, whereas the irregularly inflected forms *ran* and *mice* are stored in the lexicon and therefore involve declarative memory.

The DP model posits functional similarities between memory and language. According to this model, both facts and words involve "arbitrary relations" and therefore might share functionally similar brain structures in both acquisition and processing. Conversely, grammatical and morphological processing involves the "coordination of procedures in real time" (Ullman, 2001b, p. 46), and thus, shares characteristics of other kinds of skilled behavior. Ullman goes on to cite an extensive array of empirical evidence showing the co-occurrence of lexically based deficits in patients whose neuropathologies affect declarative memory, and rule-based deficits in patients whose procedural memory is impaired. This evidence is briefly summarized below.

Ullman's litmus test to distinguish between lexical storage and combinatorial processing is a sentence completion task that involves regular and irregular inflections. Asked to produce past tense forms in order to complete a sentence, English-speaking patients with probable Alzheimer's dementia—a pathology that affects semantic and episodic memory—made more errors for irregular than regular past tense forms (Ullman, Corkin, et al., 1997). When attempting to produce the past tense form of a verb such as *speak*, they would say ''speaked,'' ''spak,'' or ''speak,'' rather than ''spoke.'' Moreover, Ullman, Corkin, et al. (1997) have observed a significant correlation between the extent of Alzheimer patients' problems with irregular inflections and their performance on nonlinguistic declarative memory tests. Similar patterns of association have been observed in patients with semantic dementia (Patterson, Lambon-Ralph, Hodges, & McClelland, 2001) and herpes simplex encephalitis (Tyler, deMornay-Davies, et al., 2002), pathologies associated with severe loss of conceptual knowledge, as well as in posterior aphasia, a language disturbance caused by temporal damage that is often associated with semantic impairment in nonlanguage domains. Other relevant findings were obtained with Parkinson's and Huntington's disease—neurodegenerative impairments that affect the learning and execution of motor sequences. Ullman, Corkin, et al. reported that Parkinson's patients often failed to produce regular affixes, although their production of irregular past tense forms was less affected. Huntington's patients frequently overapplied the *–ed* affix (as in the errors ''lookeded'' or ''digged''). Anterior aphasia has also been reported to cause greater problems for regular forms (Ullman, Corkin, et al., 1997; but see Bird, Lambon Ralp, Seidenberg, McClelland, & Patterson, 2003 for contrasting findings in aphasia). When asked to produce past tense verb forms, these aphasic patients often failed to add the suffix *–ed* to the end of a regular verb like *walk* or a nonce form like *pilk*. Instead, they either produced the stem unchanged, added the incorrect affix (''walking''), or deformed it in some manner to resemble an irregular verb (e.g., *pilk* → ''pelk''). In summary, Ullman states that ''the findings link irregular forms to lexical and nonlinguistic semantic memory, and to temporal/temporoparietal cortex, and link regular forms to syntax, motor skill, and left frontal cortex and the basal ganglia'' (Ullman, 2001a, p. 722).

Although the DP model proposes pathways that connect memory and language thus creating common systems, it also allows for fractionation of those systems as a result of distinct neuroanatomical representation (Ullman, 2004). One of the most likely fractionations involves structures devoted to language and other nonlanguage functions (e.g., declarative or procedural memories of visual items). However, fractionations could also arise within the language domain. Of particular relevance here is Ullman's (2001a) hypothesis of a division concerning word knowledge, according to which the ''temporal lobe might be particularly important for storing word meaning, whereas temporoparietal regions might be more important in storing word sounds'' (p. 718). This raises the possibility that one might find dissociations between semantic and phonological information in patients with neuropsychological deficits. In other words, the DP model predicts both associations and dissociations between memory and language, perhaps depending on the type of neuropsychological deficit that is being examined. Pathologies that affect the underlying pathways that connect components of the system would show associations of deficits between memory and language functions that share resources of either the declarative or procedural systems. Pathologies that arise from more localized lesions might create a fractionation between components of the system, even though they are hypothesized to share common resources within the DP model.

Evidence provided in favor of the DP model has tended to focus on association of deficits between memory and language, which are interpreted as revealing common underlying processes and pathways. Relatively little evidence has been gathered for the fractionation of memory and language, in which case the relevant evidence would be the opposite of that presented so far in favor of the DP model. That is, instead of associations between memory and language, one would now predict dissociations between these systems. In this article, we present two case studies of patients who fall into this category and therefore address this second aspect of the DP model.

Connectionist Models

Connectionist models that advocate distributed rather than symbolic representations tend not to endorse the stored versus assembled distinction that is proposed in the accounts we reviewed above. Rather, these models favor the view that identical mechanisms underlie the processing of regularly and irregularly inflected forms. These mechanisms are associative in nature and resemble those that, within the W&R account, underlie the processing of irregular forms at the lexical level. Because the use of symbolic representations is eschewed in the connectionist models, the idea of combinatorial mechanisms that operate on such representations also falls by the wayside. The challenge for connectionist models is to develop networks that mimic the distinctions between regular and irregular inflections that have been observed in both normal and pathological conditions.

The first generation of connectionist models to deal with past tense inflection (Rumelhart & McClelland, 1986) made no distinction between regular and irregular forms and could not, in principle, handle selective neuropsychological impairments for regular and irregular past tense forms of verbs. However, Joanisse and Seidenberg's (1999) model seems to overcome this obstacle. This particular model relies on establishing connections between semantic and phonological features. The model incorporates separate phonological units for speech input and output. Following a requisite period of training, the model is able to simulate the behavior of individuals in tasks that involve the comprehension and production of regular and irregular past tense verbs. Semantic and phonological information ends up being differentially involved in regular versus irregular verb inflections. Semantic information becomes crucial for irregularly inflected verbs. The generation of their past tense form depends on the establishment of links between semantic representations and representations in both input and output phonology. In this way, the past tense of irregularly inflected verbs resists attraction to the statistically dominant pattern of adding *–ed* to form past tense. In contrast, the past tense forms of regularly inflected verbs are more influenced by the strong connections between input and output phonological units and are thus attracted to the dominant *–ed* pattern. Regular forms are the default responses produced by the model and are thus applied to novel verbs, unless they are attracted to a phonological cluster of irregulars such as the *ring–rang, sing–sang* cluster.

To simulate the effects of neurological deficits, connections between units were severed. When semantic connections were severed, impairments were greatest for irregular inflections, with performance decaying sharply as larger numbers of semantic connections were severed. Regulars and nonce verbs showed much shallower effects of semantic lesioning. Severing phonological units affected regular and irregular past tense generation equally in the model, but had a much greater effect on nonce verbs. With this model, Joanisse and Seidenberg (1999) were able to reproduce the selective deficits for irregular past tense verbs that have been observed in patients with acquired neuropsychological deficits. Their model not only overcomes the problem of accounting for neuropsychological dissociations between regular and irregular past tense verbs, but it also yields results that are consistent with the neuropsychological findings reported by Ullman, Corkin, et al. (1997), which show a correlation between semantic deficits and deficits for irregular past tense verbs.

Joanisse and Seidenberg's connectionist model and Ullman's DP model both link semantic memory to the processing of irregular forms. However, they diverge with respect to the processing of regular inflections. Ullman views regular inflection as the product of combinatorial mechanisms that operate within the procedural memory system; Joanisse and Seidenberg assume that the same associative mechanisms that generate irregulars also generate regulars. The two models also differ in their claims about procedural memory—only the DP model explicitly claims that this memory system shares processing space with language.

Do Declarative Memory and Inflectional Processes Dissociate?

The three models reviewed here present divergent views about the organization of language and memory and make contrasting predictions about how memory and language would break down following brain damage. In Joanisse and Seidenberg's model, damage to one part of the system creates a cascade effect within the connectionist network. Because of the fundamental interconnectedness of the systems, there is no prediction that substantial damage to one part of the system could leave other parts of the system relatively unaffected. In other words, this model predicts associations between deficits for semantic memory and irregular inflections, and it does not explicitly predict dissociations between these same deficits. The DP model, as it is currently articulated, predicts both association and dissociation between language and memory functions (Ullman, 2004). The W&R account claims that distinctions between regular and irregular inflections arise from differences in language representations—whether they are stored in the lexicon or computed—and not from how language and memory systems interact. In contrast to the DP and connectionist models, the W&R account does not explicitly predict that declarative memory deficits should lead to specific deficits in irregular inflections—the two functions are considered to be independent, possibly arising from damage to distinct brain structures. According to the W&R account, selective deficits for irregular inflections should appear following damage to specifically lexical structures rather than damage to declarative memory in general.

Such a prediction appears to fly in the face of the neuropsychological evidence reviewed above, which reveals associations between semantic deficits and specific problems with irregular inflections. However, it is possible that these associations arise because the brain structures that support lexical and memory processing reside in contiguous but functionally distinct brain regions. If this were the case, then concurrent brain damage to these contiguous brain regions might have occurred in the groups of aphasics and dementia patients who show deficits in both semantic memory and irregular past tense verbs. Anatomical contiguity is a reasonable concern if we consider that massive cortical lesions and widespread cortical damage are observed in aphasias and neurodegenerative pathologies. This possibility gains further credibility if we take into account that (a) deficits that more severely impact irregular than regular verb inflections have been documented following left temporal lesions, and (b) the left temporal areas have been linked to lexical and semantic processing, and to declarative memory in general. Thus, it is expected that a diffuse temporal lesion would impair the processing of both irregular inflections and semantic memory without necessarily involving a systematic relation between these abilities. Miozzo (2003) further notes that the available evidence from patients with semantic impairments does not rule out the presence of a lexical deficit, which could account for problems with irregular verb inflections. Hence, the W&R account remains afloat despite apparent contradictions in the data.

A crucial test for the W&R account is whether there are patients whose deficits are sufficiently localized so that processing of irregular inflections and declarative memory are not concurrently damaged. In the present article, we report on two English-speaking brain-damaged patients: AW and VP. Their acquired deficits indicate that semantic knowledge and declarative memory can dissociate from the processing of irregular inflections, thus supporting the autonomy assumptions of the W&R account. This pattern of deficits is not predicted by Joanisse and Seidenberg's connectionist model but is consistent with the current version of the DP model that allows for fractionation within the declarative memory system.

RESULTS

The results from AW and VP are presented in three sections. The first and second sections are devoted to performance on tests designed to evaluate the intactness of established semantic knowledge and new episodic knowledge. In the third section, we report on elicited production of inflected words. Preliminary data from patient AW indicate that, although she fails to produce irregular inflections, retrieval of semantic information remains intact (Miozzo, 2003). In the present study, we report new data that show the intactness of AW's semantic and episodic memory processing.

Semantic Memory Tasks

Subtle semantic memory deficits can be revealed only with tasks that demand the retrieval of detailed semantic information. For this reason, only tasks of this type were administered to AW and VP. In three matching tasks, the patients were presented with three semantically related items and were asked to point to the two items that were most related. Task 1 (from Hillis & Caramazza, 1995) and Task 2 (from the BORB, Riddoch & Humphreys, 1993) involved pictures. For example, one trial included the pictures web, spider, and ant—web and spider were the expected response. In Task 3 (from Miozzo, 2003), triplets of written words were presented (e.g., to walk, to stroll, and to run). (The experimenter read the words aloud to circumvent reading problems.) AW performed well in these tasks (correct responses: Task 1 = 32/32, Task 2 = 29/30, Task 3 = 212/214). Conversely, VP performed less accurately than normal controls [Task 1 = 25/32 (78%); Hillis & Caramazza, 1995 reported perfect accuracy for normal controls; Task 2 = 21/30 (70%), $z = -2.7$; Task 3 = 184/214 (86%), $z = -33$].

In another task, the patients were instructed to provide comprehensive verbal definitions of auditorily presented words of low to medium frequency (<30 per million; mean = 8.7; Francis & Kucera, 1982). VP defined only 10 words, whereas AW defined 25 words (see examples in Table 1). AW's definitions were correct and exhaustive. Two judges examined the accuracy of each piece of information provided by AW. The judges unanimously rated 83/85 (98%) pieces of information as correct. VP's definitions, on the other hand, were qualitatively inferior and lacking in crucial details. For example, for *tar* she did not mention that it is used to pave roads. The definitions were poorly organized and occasionally incorrect. For example, her description of *beaver* seems to better describe *groundhog*.

Semantic confusions such as *bus* → ''van'' are commonly produced in naming tasks by patients with se-

Table 1. Examples of Verbal Descriptions Provided by AW and VP

Concept	*AW's Description*	*VP's Description*
Beaver	He builds a little bridge on a stream; cute; fuzzy; flat tail.	An animal. They burrow, so they dig out from underground . . . messing up a lot of ground.
Tar	Black and you use it to fix up a stone wall, and to make the ground, the road.	That's a sticky stuff. It adheres to the surfaces.
Maze	You walk in it. You walk through it and try to find your way out. Made of bushes. In books, all kinds of lines and you go through and find the other side.	Made out of ground dirt. I've gone to one of these.
Clown	Always in circus, for people, white face, red lips, big nose. He's funny.	So funny . . . Supposed to make you laugh. . . usually painted in colored paint.
Ghost	White. I don't think there is any. When someone puts a sheet over him it makes believe he's a [ghost].	Havent's heard much about ghosts. Nothing special. A spiritual character.
Chisel	You use it to chip away, to make things more smooth.	Chiseling out something. . .
Yacht	Big boat for rich people.	Usually luxurious; a boat.
Famine	When you are very low on food and you are hungry you have it.	Something you don't have food.

mantic impairments. Errors of this type were observed only three times within the corpus of 114 errors that AW made while naming 603 pictures and verbal definitions (94% of her errors consisted of picture descriptions or failures to produce a name; errors of this type are symptomatic of problems with lexical retrieval). By contrast, semantic errors predominated with patient VP: Out of 65 errors that she made in naming 245 pictures, 38 errors (58%) were semantic. The remaining errors included 19 circumlocutions (e.g., *plant* → ''leaves in a pot''; *funnel* → ''it is supposed to drain''), 6 visual confusions (e.g., *scale* → ''radio''), and 2 omissions (we will analyze the nature of VP's naming errors in the Discussion).

To summarize, no signs of semantic impairment were evident in AW from the tests presented in this section. The opposite conclusion holds for VP: In not one test did we find evidence that her semantic memory was intact.

Episodic Memory Tasks

To further examine declarative memory, we assessed encoding, consolidation, and retrieval of new episodic memories concerning facts, words, geometric figures, faces, and scenes. The tests varied in terms of materials (pictures, faces, words), presentation modality (visual vs. auditory), testing modality (recognition, recall, source memory), and interval (immediate vs. delayed memory) (see Table 2 for details). AW's word retrieval deficit and her severe verbal STM impairment restricted the choice of declarative memory tasks to those that exclude low-frequency words and that do not make demands on STM. Issues related to STM deficits also apply to patient VP, whose problems in figure copying further limit the range of tests suitable for her. Testing took longer with VP than AW, because VP was easily distracted, and instructions had to be repeated because she often forgot them. As a result, we decided to administer only a subset of the tasks used with AW.

The scores of the patients and those of their age-matched controls are shown in Table 2. Once again, AW performed almost flawlessly on these tasks, whereas VP showed severe deficits. VP's scores were within the range of controls in the scene free recall test. However, a qualitative analysis of VP's responses more clearly reveals the inaccuracy of her memory for scenes. On only one occasion was she able to indicate what the people portrayed in the scene had been doing, and even the accuracy of this memory is in doubt as she reported the same activity for several different scenes. AW's only impaired score ($z = -2$) appeared in List A of the California Verbal Learning Test (CVLT), a result that we in part anticipated given her verbal STM deficit. This task requires the repetition of 16 aural words. In the first presentation of List A, AW showed no recency effect, the hallmark of STM: She failed to recall any of the five most recent words of the list. Nonetheless, with list repetition, recall relies less on STM and more on episodic memory. By the fifth presentation of List A, AW recall improved to 10/16 words ($z = -0.5$).

Production of Regularly and Irregularly Inflected Words

We used an elicitation task to test the extent to which regular and irregular inflections were available to AW and VP. This task required participants to produce the past tense (''ate'') or the past participle (''eaten'') of a verb stem (*eat*) spoken by the experimenter, or to produce the plural of a noun (''barns'') that the experimenter presented in its singular form (*barn*). The three types of inflections were presented in separate blocks. Materials were from Miozzo (2003). For each inflection, regular and irregular forms were equally represented and were closely matched for both whole-word frequency and stem (lemma) frequency (paired *t*s with *p*s > .18; norms were from Francis & Kucera, 1982). Because this task imposes little demand on semantic processing, it is suited to testing the prediction that semantics is not assumed to play a critical role in inflection production. If this is the case, then VP would be expected to perform well with both regular and irregular inflected forms. On the other hand, because of her anomia, AW might encounter problems in this task. AW's anomia is associated with a deficit in accessing word phonology from the lexicon. For example, when asked to produce a verb in response to a picture of an action, AW is likely to encounter problems with regular and irregular verbs alike, because the retrieval of both verbs involves lexical access. However, if the task requires the patient to produce an inflectional variant of a verb that is presented by the experimenter (e.g., *walk*), then lexical access for the inflected form (*walked*) is not required if the inflected form can be derived through a rule-based process such as adding *–ed* to the already available stem (*walk*). If irregular forms require separate lexical access from the stem, then patients such as AW should perform poorly on the past tense elicitation task with irregular forms.

AW's results supported these predictions (see Table 3). Although she was as accurate as age-matched controls with regular inflections (range: 95–99%), she was far less accurate with irregular inflections (range: 71–43%). All of these differences between regular and irregular forms were highly significant (χ^2s > 13, *p*s < .001). Two aspects of AW's data with irregular verb forms are worth emphasizing (see Miozzo, 2003 for details). First, only about a third (34%) of AW's errors with these forms consisted of over-regularizations, that is, responses in which *–ed* is appended to the stem, as in ''speaked'' or in ''writed.'' This result demonstrates that information about the regular/irregular status of the verb was (at least partially) available to AW, and her correct

Table 2. Scores in Episodic Memory Tests: Patients AW and VP

	AW		*VP*	
Test	*n correct/Total*	*Z-scores*[a]	*n correct/Total*	*Z-scores*[a]
Figure Recognition				
(a) CVMT[b]				
Immediate recognition	83/112	(cutoff 64)	48/112	(cutoff 64)
d' (controls' mean = 1.27)	2.22		−.03	
Delayed recognition	7/7	(cutoff 3)	0/7	(cutoff 3)
(b) Benton Visual Retention Test[c]	8/10	0	–	–
Face Recognition				
(a) Warrington (1984)[d]	43/50	−0.2	29/50	−3.5
(b) Weschler Memory Scale[e]				
Immediate recognition	39/48	+1.3	–	–
Delayed recognition	37/48	+1.0	–	–
Word Recognition				
(a) CVLT[f]				
20-minute delay	14/16	−0.5	12/16	−2.0
d' (controls' mean = 3.0)	3.0		0.4	
30-minute delay	16/16	+0.5	10/16	>−3
(b) Warrington (1984)[g]	42/50	−0.2	26/50	−3.7
(c) Wegesin, Friedman, Varughese, and Stern (2002)[g]	424/512	0	–	–
Figure Delayed Free Recall				
Rey–Osterrieth	15/36	+0.5	–	–
Scene Free Recall				
Weschler Memory Scale[h]				
Immediate recognition	30/64	−0.3	11/64	−1.3
Delayed recognition	31/64	0	15/64	−0.6
Word Free Recall				
CVLT[i]				
Immediate List A				
Trial 1	3/16	−2.0	2/16	−2.5
Trial 5	10/16	−0.5	1/16	−3.5
Immediate List B	3/16	−1.0	2/16	−1.5
Short-delay	7/16	−0.5	2/16	−2.0
Long-delay	9/16	−0.5	1/16	−2.5

Table 2. (*continued*)

Test	AW		VP	
	n correct/Total	*Z-scores*[a]	*n correct/Total*	*Z-scores*[a]
Cued Word Recall				
CVLT[i]				
Short-delay	8/16	−1.0	4/16	−2.5
Long-delay	8/16	−1.0	4/16	−2.5
Source Memory (Words)[g]				
Wegesin et al. (2002)	205/323	−0.4	–	–

[a]Each patient's scores were compared to those of the control group matching most closely for age and education.

[b]*Continuous Visual Memory Task* (Trahan & Larrabee, 1983). Participants recognize which figures appear more than once upon figure presentation. In the delayed task, the target is shown along with six visually similar foils.

[c]A figure is studied for 10 sec and is then presented for recognition along with three foils.

[d]Participants provide a yes/no judgment about a face's pleasantness. Pairs of old/new faces are presented for recognition.

[e]Participants study each face for 2 sec, and perform an old/new judgment task.

[f]*California Verbal Learning Test* (Delis, Kramer, Kaplan, & Ober, 2000). Participants listen to a word list and indicate whether the words were part of an earlier list.

[g]Written words are shown for ''pleasant/not pleasant'' judgment and then presented for forced-choice recognition. Wegesin et al.'s test also requires a source judgment (i.e., whether the words were part of List 1 or List 2). Words were read out loud to circumvent reading difficulties.

[h]Participants study a scene for 10 sec, and as soon as it is removed are asked to recall which members of the family were in the scene, what have they been doing, and in which quadrant.

[i]*California Verbal Learning Test* (Delis et al., 2000). Participants recall aurally presented word lists. In the cued recall task, participants provide the words from List A that were part of a certain category (e.g., animals).

performance with regular forms cannot be solely attributable to a strategy of indiscriminately appending an *–ed* affix to the end of all verb stems. Second, a logistic regression analysis revealed that lemma (stem) frequency was a reliable predictor ($p < .05$) of AW's responses with irregular verbs. AW showed a clear frequency effect for irregular verbs, being more successful at retrieving irregular verbs with high as opposed to low stem frequency. Frequency effects of this sort are generally considered to be the signature of lexical access (e.g., Pinker, 1991).

Contrasting results were obtained with VP. Her accuracy rates were high for regular and irregular forms of past tenses (99% vs. 97%), past participles (99% vs. 95%), and noun plurals (100% vs. 90%). VP's two errors with irregular plural nouns were *music* → ''musica'' and *person* → ''personae''—revealing a sophisticated rather than degraded knowledge of English irregular plurals. The list of irregular plurals in the noun elicitation task did not contain infrequent forms such as *curricula*, *octopi*, or *symposia*, because we felt that these forms were not likely to be part of AW's premorbid vocabulary. In contrast, infrequent forms were readily available to VP, who was able to produce the irregular plurals *alumni*, *bacteria*, *cacti*, *criteria*, *curricula*, *foci*, *fungi*, *octopi*, *phenomena*, *stimuli*, *syllabi*, and *symposia*. This more anecdotal evidence further attests to the intactness and superiority of VP's knowledge of irregular forms. The implications of the performance of VP and AW in the elicitation task will be examined in the Discussion.

DISCUSSION

The data reported here demonstrate a double dissociation between deficits selectively affecting irregular inflections and declarative memory. Patient VP performed poorly in tasks tapping semantic and episodic memory, whereas her ability to retrieve inflections of English verbs and nouns was intact. The opposite pattern emerged with patient AW, who performed almost flawlessly in declarative memory tasks but showed selective deficits with irregular inflections.

It should be noted that VP's findings are different from those reported in amnesia by Kensinger, Ullman, and Corkin (2001). The celebrated amnesic patient HM also demonstrated an intact ability to produce irregularly inflected forms. Crucially, however, HM's amnesia involved the acquisition of *new* episodic memories, whereas access to established memory was (mostly) preserved. VP's declarative memory deficit was more widespread and affected established memories as well, as indicated by her failure in tasks that demanded access to the semantics of objects and verbs. In contrast to HM, VP's ability to retrieve irregular inflections appeared in the context of a *widespread* declarative memory deficit

Table 3. *n* (%) Correct Responses in the Elicitation Tasks

		N (%) Correct		
Elicitation Task	*N*	*AW*	*VP*	*Controls' mean*[a] *(range)*
Past Tense				
Regular forms *walk* → "walked"	95	91 (96)	94 (99)	93 (98) (92–94)
Irregular forms *eat* → "ate"	95	68 (71)	92 (97)	91 (96) (90–92)
Past Participle				
Regular forms *walk* → "walked"	97	96 (99)	96 (99)	96 (99) (96–99)
Irregular forms *eat* → "eaten"	97	57 (59)	92 (95)	94 (97) (94–95)
Noun Plural				
Regular forms *mink* → "minks"	21	20 (95)	21 (100)	21 (100) (21–21)
Irregular forms *mouse* → "mice"	21	9 (43)	19 (90)	21 (100) (21–21)

[a]Three high school educated controls whose ages ranged between 67 and 74.

and demonstrates a dissociation of brain mechanisms devoted to established knowledge about objects and word forms, respectively.

In addition to the differences in the deficit profiles of AW and VP, there were some similarities, which must also be accounted for. In the picture naming task, both patients produced errors that consisted of omissions and circumlocutions (descriptions of picture content). However, only VP showed extensive errors involving semantic substitutions (e.g., *bus* → "van"). VP's problems with the retrieval of semantic information could explain her errors in picture naming. When semantic processing is degraded, it is possible that none of the lexical nodes reaches the activation level required for name selection, so picture descriptions or omissions occur in substitution. Elicitation of inflected past tense or plural forms, given the stem, only requires access to the lexical properties of words (phonological and morphological). Access to semantic information is not required. It does not matter what a word means if your task is to make it past tense or plural. Therefore, it is relatively unsurprising that VP's semantic deficit failed to affect performance on this task. However, if we interpret AW's deficit as one affecting the availability of lexical information, then her impaired performance with irregular stored forms is also to be predicted. One would also predict problems with accessing uninflected stored forms, as would be required for the picture naming task. Because AW did not have problems with semantic processing in general, one would predict that errors would involve scrambling for related semantic properties, but not semantic confusions. Again, AW's data fulfill these predictions, so as to provide further support to our account of why AW and VP each produced certain types of errors.

Similar dissociations between semantic and lexical processing have been observed in other domains of lexical knowledge in the literature. Like AW, other patients with anomia have shown a preserved ability to access the meanings of words about which they failed to retrieve lexical information, including syntax and phonology (e.g., Miozzo & Caramazza, 1997; Key & Ellis, 1987). The double dissociation observed in patients AW and VP, along with other converging neuropsychological evidence, suggests that mechanisms responsible for lexical processing reside in regions that are neuroanatomically distinct from those involved in processing general declarative memory. Thus, in conditions of brain damage, each of these regions can be selectively impaired and give rise to deficits restricted to lexical knowledge or declarative memory. This hypothesis gains plausibility if we consider that different lesion sites seem to be associated with semantic and lexical deficits. All patients impaired in the irregular past tense (including our patient AW) present with left temporal lesions. Tyler, deMornay-Davies, et al. (2002) documented that the deficits for irregular past tense verbs *and* semantic processing observed in their four patients were consistently associated with extensive damage to the left inferior temporal gyrus. This area appears to be spared in AW; her lesion affects the medial and superior temporal regions. Data from functional neuroimaging studies link left inferior temporal areas to semantic processing (see Martin, Ungerleider, & Haxby, 2000, for a recent review). Hopefully, future evidence from patients or neuroimaging studies will help us better define the brain regions associated with lexical and semantic processing.

Next, we examine the ramifications of the data of patients AW and VP for the words and rules account, Ullman's DP hypothesis, and Joanisse and Seidenberg's connectionist model.

The Words and Rules Account

The W&R account assumes (1) a distinction between regular and irregular inflectional processes and (2) the separation of the lexicon and semantics. The pattern of associations and dissociations that we report in our patients is as anticipated by this model. AW's problems with lexical retrieval exactly predict her deficit with irregular but not regular inflections. VP's severe semantic deficit does not predict any problems in the tasks we used to elicit morphological forms, and there were none. Taken together, the data of AW and VP lend strong support to the W&R account.

The Declarative Procedural Model

Our findings with AW and VP are not incompatible with the DP model if it is assumed that the declarative memory system includes brain structures specifically devoted to the processing of semantic and lexical knowledge. By further assuming that irregular inflections are stored in the lexicon, it is possible to account for VP's ability to produce irregular inflections, even if semantic processing was impaired, and for AW's failures with irregular inflections, even if semantic processing was intact. This conclusion actually echoes Ullman's (2001a) own speculations about the neuroanatomical underpinnings of language processing, wherein left temporal structures are involved particularly with semantic processing, but temporo-parietal regions are more important in storing word phonology (see also Ullman, 2004). If we assume that specific deficits for irregular inflection involve phonological representations rather than semantic representations, then this framework would predict the current findings.

Once a modularity of this kind is introduced within the declarative memory, the crucial question becomes what causes relatively independent components to form a cohesive system. Our neuropsychological findings clarify at least one aspect of the structure of declarative memory. Namely, the structure is such that the semantic and lexical components do not break down together in conditions of brain damage—rather, each of them can be selectively impaired or preserved. Although the precise nature of such structure is at present unclear, the conclusion that stark dissociations would emerge within such a structure seems to be inescapable in light of the results we have observed with patients AW and VP.

There is an additional implication of our results we should consider, which concerns the use of neuropsychological data to test the DP model. To date, the co-occurrence, in several neuropathologies, of deficits affecting irregular inflections and various forms of declarative memory has been cited as one of the strongest results in favor of the hypothesis that the declarative system includes linguistic knowledge. The demonstration of clearcut dissociations between these same deficits severely weakens the possibility of drawing unequivocal conclusions on the basis of the associative evidence widely cited thus far. As neuropsychologists have consistently warned us (e.g., Coltheart, 2001), associations of deficits can arise from independent but neuroanatomically contiguous regions that are both affected by extensive lesions, which are the norm (rather than the exception) with neuropsychological patients. This possibility gains strong plausibility in light of the dissociations we documented in the present article. What our results have revealed is that support for the DP model can hardly be obtained on the basis of dissociations and associations of neuropsychological deficits alone. Given the current state of knowledge about the neuroanatomical underpinnings of language and memory, it is impossible to establish whether the associations of language and memory deficits reflect the neurofunctional organization of hypothesized systems or rather the probabilities with which contiguous but functionally independent brain structures are impaired in conditions of acquired neuropathologies.

The Connectionist Model

Joanisse and Seidenberg's (1999) connectionist model was able to predict differential deficits for regular and irregular inflections of real and nonce verbs when specific connections within the model were severed. In particular, more severe deficits for irregular inflections followed damage to the semantic component. Joanisse and Seidenberg use this result to explain the correlations between deficits for semantics and irregular inflections that have been reported in the neuropsychological literature. The data of AW and VP are evidently at odds with this conclusion. In fact, a severe deficit for irregular inflections was observed in AW despite her intact semantic memory. Conversely, processing of irregular inflections remained intact in VP despite her noticeable semantic deficit. Another inconsistency concerns the selectivity of our patients' deficits. Regular and irregular verb inflections were both impaired in Joanisse and Seidenberg's model when phonological or semantic units were severed. However, VP did not have problems with either kind of verb—despite her semantic deficit; and AW was not impaired with regular verbs—despite her failures to access word phonology. These data clearly do not support the particular instantiation of connectionist model proposed by Joanisse and Seidenberg (see also Ullman, Pancheva, et al., 2005; Miozzo, 2003; Tyler, Randall, & Marslen-Wilson, 2002 for further similarly problematic data for this model).

One possibility for making Joanisse and Seidenberg's (1999) model compatible with our data is really quite simple. The "semantic" nodes in their model are not semantic in the sense of being a distributed set of features in some associative structure, hence, there are no generalizations on the basis of semantic features. In its undamaged state, the network does not know that *to walk* and *to run* have anything in common, and thus, makes no generalizations based on such common semantic properties. This is because the "semantic" nodes are actually numerical indices, each corresponding to a different word in the lexicon, plus one unique index to mark past tense. They are called ''semantic'' only because Joanisse and Seidenberg choose this label. What these nodes actually do is to individuate lexical items in the form of nodes that are empty of content. These nodes could potentially connect to other layers in the network, but only connect to phonological features in the model. Because the lexical nodes connect only to phonological input and output networks in the model, lesioning of these nodes nicely simulates AW's profile of anomia and selective deficits with irregular inflections. Unfortunately, this interpretation of the model no longer allows it to explain the association between semantic memory deficits and irregular inflection deficits found, for example, in Alzheimer's patients. Any changes in the model to account for patients of this type, perhaps by incorporating connections to semantic networks, would also have to account for the dissociation between semantic deficits and irregular inflectional processing we have observed in patient VP.

Conclusions

In this article, we contrasted three approaches to explaining the relation between the lexicon and declarative memory. The neuropsychological evidence we documented in the article shows unequivocally that lexical and declarative memory processing can be selectively damaged in conditions of acquired brain damage. This evidence favors the conclusion that language and memory processing are represented in partly independent brain structures, and supports cognitive models that assume a certain degree of modularity. The data we reported also suggest functional fractionations within the linguistic domains, between forms stored in the lexicon (word-stems and irregular inflections) and forms that are likely to be obtained by means of combinatorial processes.

METHODS

Patient Description

Case AW

A comprehensive description of AW's cognitive deficit was presented in Miozzo (2003). Here we summarize the major points and emphasize the aspects of AW's impairment that determined which declarative memory tests were suitable. AW, a native English-speaking, right-handed woman, is a homemaker with a high school education. In 1999, she suffered a stroke. A brain CT scan taken 3 days after her stroke showed lesions of the basal ganglia, the frontal white matter, and of the medial and superior temporal areas. The stroke left her with right-arm hemiparesis. We started to test AW 2 years after her stroke, when she was 71 years old. AW suffers from anomia, a deficit of word retrieval in speaking. Her speech is fluent and grammatical, but is punctuated by frequent pauses when she struggles to find the right word. Her performance in the naming task from the BDAE (Goodglass & Kaplan, 1972) provides an indication of the severity of AW's word retrieval deficit: She successfully named only 31/50 pictures (62%; $z = -3$). Various tests examined whether AW could access the phonology of the words that she could not name. While searching for the target word, she was asked to indicate (between two alternatives) the onset consonant, syllable number, or the article (''a'' vs. ''an'') of the target word, or whether a certain word rhymed with the target word. AW scored at chance levels in all of these recognition tasks (see Miozzo, 2003, for details). Repetition of auditorily presented words was intact, a finding that suggests that articulatory difficulty was not the cause of her anomia. AW's ability to read both words and nonwords aloud was impaired. Verbal STM was impaired: AW failed to repeat sequences composed of more than three digits, and she could only repeat backward sequences of two digits. Auditory comprehension of single words and short sentences was intact.

Case VP

VP is a native English-speaking, right-handed woman with a college education. At the time of testing she was 86 years old. She had worked as secretary for a scientific laboratory. In November 2001, she was hospitalized because of intraparenchymal hemorrhage (lobar hemorrhage), which caused constructional deficits and language impairment. A CT scan conducted at time of hospitalization revealed a left superior parietal lesion. Unfortunately, more recent neuroimaging records were not available. Upon her discharge from hospital, she became a permanent resident of a nursing facility. The speech pathologist who tested VP at the time of her admission to the nursing facility diagnosed ''a mild to moderate expressive aphasia'' and described her speech as ''fluent and grammatical, with decreased word finding and semantic paraphasias.'' VP participated in our study between March and May of 2002. VP's scores in the Mini Mental Status Exam were low and fluctuated from 15 (April 2002), to 23 (December 2002), to 21 (July 2003). In the most recent neuropsychological examination (July 2003), it was suspected that VP's cognitive deficit reflected an underlying degenerative process of dementia type, although a diagnosis of dementia was never reached conclusively because it could not have been ruled out that her cognitive deficits resulted from the stroke.

We tested various aspects of VP's language functioning prior to starting our study. Naming was compromised: VP named correctly only 34/60 (57%) pictures from the BDAE (Goodglass & Kaplan, 1972) ($z < -3$). Grammatical processing appeared to be intact in speech production, as no grammatical errors were detected from samples of VP's speech. Further evidence showing intact grammatical processing comes from an auditory grammaticality judgment task, in which VP was able to discriminate ill-formed sentences such as ''They want to meet the girl that you said were pretty'' from grammatical sentences (10/10 correct; elderly control mean = 8.8/10). Auditory sentence comprehension was impaired. When presented with an auditory sentence (e.g., ''the truck is pulling the man'') and asked to discriminate between the picture corresponding to the sentence and a foil (a picture showing a man pulling a truck), VP responded correctly 11/16 times (elderly controls = 15.8, $z = -15$). The latter result cannot be accounted for by a grammatical deficit, as VP used correct grammatical structures to describe the content of the same pictures. Her poor performance in the comprehension task was probably the result of her severe verbal STM deficit. VP could not repeat sequences longer than four digits, and was unable to repeat backward even two-digit sequences. She also failed to repeat plausible sentences spoken by the examiner. Three results indicate preserved word auditory recognition: (a) good word/nonword discrimination (19/20 correct; nonwords were obtained by changing one phoneme of familiar words); (b) perfect score (20/20) in a same/different task (words differed by one phoneme); (c) perfect repetition of 10 inflected and derived words.

The results of a comprehensive reading test revealed intact reading aloud of words with regular and irregular spelling, of high or low frequencies (zs > 0). VP could read inflected and derived words (59/60; $z = -.06$), and nonwords (9/10 correct). However, she had problems in a matching task in which she was to indicate which of four written words had been spoken by the experimenter—the alternatives were the target (bottle), a semantically related foil (jug), an orthographically/phonologically related foil (battle), and an unrelated foil (plan). VP scored 8/10 (controls' mean = 10)—in both errors she chose the semantically related foil. The latter finding fits with the hypothesis that VP's semantic processing is impaired.

VP's written spelling was mildly impaired. She correctly wrote the names of 6/10 pictures that she had successfully identified ($z = -4.1$). In writing to dictation, VP scored similarly with words with regular versus irregular spelling (93% vs. 89%; $\chi^2 < 1$) and with words with high versus low frequencies (94% vs. 82%; $\chi^2 = 2.5$, $p > .10$; materials were from the Johns Hopkins Dysgraphia Battery; Goodman & Caramazza, 1985). Substitutions (e.g., dog → dug) and perseverations (e.g., true → truee) of single letters accounted for the majority of VP's errors in the written spelling tasks (13/15, 87%). The absence of frequency or regularity effects seems to rule out problems in accessing word orthography. VP's errors probably originated from a more peripheral deficit, at the level of the fine-grain movements implicated in writing. Such a deficit could also have affected VP's copying of drawings, which was severely impaired—she failed to copy even simple geometric figures.

VP's excellent reading ability rules out the possibility that visual processing problems are the cause of her poor copying skills. To test whether VP's visual recognition of pictures was impaired, we administered a task from the BORB (Riddoch & Humphreys, 1993). This task required VP to indicate which of two pictures presents the target object from a different and unusual perspective; the foil was visually similar to the target. VP's responses (21/25 correct) were within age-controls' range ($z = -0.2$; norms from Riddoch & Humphreys, 1993).

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