Neuropsychologia 48 (2010) 2427–2436

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

A selective deficit for inflection production

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ARTICLE INFO

Article history:
Received 10 April 2009
Received in revised form 24 February 2010
Accepted 1 April 2010
Available online 18 April 2010

Keywords:
Morphology
Lexical processing
Inflections
Lexical deficits

ABSTRACT

We report the case of an English-speaking aphasic patient (JP) with left posterior-frontal damage affecting the inferior frontal and precentral gyri. In speaking, JP was impaired with the regular inflections of nouns and pseudonouns, making errors like "pears" instead of *pear* or "door" for *doors*, while the spoken production of noun stems and irregularly inflected nouns (*teeth*) was preserved. JP's noun inflection errors stemmed from problems with inflection selection rather than a lack of understanding of concept numerosity or phonological deficit. Evidence that inflection deficits occur independently of semantic and phonological impairments supports accounts that propose dedicated neural substrates for morphological processes and raises a challenge for connectionist models that do not incorporate specific mechanisms for morphology. JP's results also demonstrated a lexical deficit selectively affecting the retrieval of verb stems and a more severe impairment for verb vs. noun inflections. JP's verb production deficit suggests a close interaction between inflectional and lexical processes probably reflecting the fact that English inflection choice in part depends on stem information stored in the lexicon.

Inflections are used in many languages to indicate a variety of features about the meaning and the grammatical characteristics of words. They denote number in English nouns, for example, and an assortment of features in other languages, including gender, size and specific locations (Haspelmath, 2002). In many languages, inflections are realized by changes in the phonology of word endings. For example, the plural of English nouns is generated by adding the phonemes /*s*/, /*z*/, or /*es*/ to the end of the word. Inflected words can be analyzed as having two components: stems bearing the bulk of word meaning and inflections denoting auxiliary grammatical and semantic features. The notion that stems and inflections are supported by partially distinct cognitive processes has been endorsed by several linguistic theories (e.g., Albright & Hayes, 2002; Aronoff, 1994; Halle & Marantz, 1993; Jackendoff, 2002), has been the predominant view in psycholinguistics (e.g., Caramazza, Ludanna, & Romani, 1988; Clahsen, 1999; Gordon, 1985; Pinker, 1991, 1999; Schreuder & Baayen, 1995; Taft, 2004), and has been incorporated into neurocognitive accounts of language (Marslen-Wilson & Tyler, 2007; Ullman, 2001). A natural prediction of this view is that focal brain lesions could selectively affect the processing of either stems or inflections. Here we address this issue from the perspective of language production and document an individual (JP) whose acquired brain damage affected inflections but spared stems, a selective dissociation JP exhibited with nouns but not with verbs.

The words-and-rules account of inflectional processing has received considerable attention in psycholinguistics. Under this account, word stems are represented in the lexicon, the memory system dedicated to storing information about words specifically their meaning, sounds and grammatical features (Marslen-Wilson & Tyler, 1998; Pinker, 1991). The stems are assembled with the proper inflections by combinatorial mechanisms operating on rule-like knowledge. Thus, the production of a word like *cats* requires retrieving the stem *cat* from the lexicon and assembling it with the plural inflection *-s* through processes that combine stems and suffixes in accordance to the rules of the language. A neurocognitive view of the words-and-rules account proposes that stems are supported by left temporal structures, whereas combinatorial mechanisms are associated with left-inferior-frontal regions (Ullman, 2001). These types of accounts make two clear predictions about the possible effects of language deficits on the production of inflected words. First, deficits affecting the lexicon could selectively impair word stems. Second, to the extent that combinatorial mechanisms can be selectively impaired, deficits can be restricted to inflections.

A selective impairment to either stems or inflections can be explained by an alternative account of inflectional processing proposed within the framework of connectionist theories (Hahn &

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doi:10.1016/j.neuropsychologia.2010.04.001

Nakisa, 2000; Joanisse & Seidenberg, 1999; Mirkovic, MacDonald, & Seidenberg, 2005; Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986; Seidenberg & Gonnerman, 2000). Massively interactive and distributed systems that encode the semantics and phonology of words enable speakers to acquire the arbitrary relation between meaning and sound. Inflections are learned and encoded using the same distributed systems representing semantics and phonology. In contrast to the words-and-rules account, inflections do not depend on 'hard-wired' mechanisms specifically devoted to morphology, instead, the representation of inflections would emerge naturally from the interaction between systems representing semantics or phonology. The absence of mechanisms specifically devoted to inflections, however, would not prevent stems and inflections from being processed differently within connectionist architectures. Processing differences between stems and inflections can be explained in different ways (Plaut & Gonnerman, 2000), though data directly speaking to this issue (e.g., from computer simulations) are presently lacking. Distinctions between stems and inflections could naturally arise from critical differences concerning the meaning and phonology of these two components. For instance, the meaning of stems varies more extensively than that of inflections, which generally encode a limited range of fixed semantic features. Moreover, the relationship between meaning and sound is far more arbitrary for stems than for inflections. The plural of English nouns provides a characteristic example of this; it is only realized by three types of phonemes (/s/, /z/, /es/), which vary quite predictably and only occur at word end.

These differences could affect the connections and representations corresponding to stems and affixes. Because of their predictability and frequency, inflections could form rather strong connections at the phonological level. Furthermore, having quite an impoverished semantics and phonology, inflections would tend to have more "local" representations. In contrast, the variability and richness of the meaning and sounds of stems would be reflected by more distributed representations. These major representational differences could also have consequences for the way in which stems and inflections are affected by brain damage. The degree of distribution of their representations and the strength of their connections are both variables that could determine the extent of damage incurred by stems and inflections when semantics and phonology are impaired. Computer simulations of cognitive deficits have represented a primary form of testing for connectionist accounts of neuropsychological impairments. Although there have not been computer simulations of deficits predominantly affecting stems or inflections, it is reasonable to expect that such deficits would emerge from damaging connectionist networks. In this respect, connectionist accounts are in accord with words-and-rules accounts—both can potentially explain selective deficits for stems or inflections.

Nevertheless, words-and-rules accounts can be distinguished from connectionist accounts by a careful analysis of selective stem or inflection deficits. According to connectionist accounts, impairments that more severely affect either stems or inflections can only be observed in the context of selective damage to semantic or phonological representations or the connections that mediate access to such representations. According to words-and-rules accounts, deficits for inflections can appear in a "pure" form, without additional semantic or phonological deficits. Selective stem or inflectional deficits that cannot be explained by either semantic or phonological impairments are envisaged by the words-and-rules accounts and are difficult to reconcile with the connectionist accounts.

The existence of selective stem deficits has been confirmed by several lines of evidence derived from the analysis of two types of acquired language deficits: agrammatism and conduction aphasia. Agrammatic speaking is punctuated by neologisms, newly coined words that often bear little resemblance to the intended words. Researchers have often observed neologisms in which correct inflections were combined with wrong stems, as in the error "I'm just *persessing* to one... I persess" cited by Caplan, Kellar, and Locke (1972). This has been taken as evidence that stems and inflections are supported by partially different mechanisms (Buckingham & Kertesz, 1976; Butterworth & Howard, 1987; Semenza, Butterworth, Panzeri, Semenza, & Ferreri, 1990). Other results suggestive of a relative preservation of inflections come from patients with conduction aphasia some of whose errors in repetition frequently involved the stems but rarely, if at all, the inflections (Caplan, Vanier, & Bakes, 1986; Caramazza, Papagno, & Ruml, 2000; Miceli, Capasso, & Caramazza, 2004; Wilshire & McCarthy, 1996). Perhaps the most dramatic dissociation of this kind was documented with verbs in patient HG by Shapiro and Caramazza (2003a). This patient showed selective problems with the retrieval of verb stems as demonstrated, for example, by frequent errors in using verbs for naming actions or events. Nevertheless, inflections were invariably correct even when the wrong verb stems were produced.

Errors affecting the spoken production of inflections have been commonly observed in aphasia across different languages (Menn & Obler, 1990). However, there have been relatively few cases demonstrating more difficulties in producing inflections than stems. This pattern was mostly observed in tasks that indirectly tap into speech production, such as reading aloud and repetition (for a review, see Allen & Badecker, 2001; Badecker & Caramazza, 1998). For example, while inflections and other bound morphemes were often read incorrectly by patient SJD (Badecker & Caramazza, 1991), letters forming the stems were read far more accurately. Moreover, using an ingenious test involving homophonic pairs like *links*/*lynx*, it was demonstrated that SJD's errors were far more common with inflected words (*links*) than with their monomorphemic "twins" (*lynx*).

Along with these inflectional errors, SJD made both semantic and phonological errors in reading. Indeed, the few other patients described with selective inflectional deficits also appear to have semantic or phonological deficits that significantly complicated the interpretation of their inflection errors. As we have mentioned before, the presence of semantic or phonological deficits is expected by connectionist accounts and the results obtained in previous neuropsychological reports can be taken as providing some support for such accounts. The co-occurrence of semantic and phonological deficits is not necessarily a problem for words-and-rules accounts; indeed, these deficits can appear independently from those affecting inflections. However, their co-occurrence limits the possibility of finding selective inflection deficits that would directly support words-and-rules accounts.

In this paper, we examine the pattern of errors produced by patient JP, a native English speaker. JP was shown to make inflectional errors in a number of tasks. Neuropsychological investigation of English inflections is complicated by the fact that many words do not bear overt affixes. A case in point is represented by English nouns: their singular forms are unmarked (*cat*, *lunch*); inflections only surface in the plural (*cats*, *lunches*). Plural/singular substitution errors like *cats* → "cat" may reflect the phonological complexity of plural nouns rather than a genuine problem with inflection processing. Singular/plural substitution errors like *cat* → "cats" are crucial: their appearance weakens a phonological explanation as much as it strengthens the hypothesis of an inflection deficit. These methodological concerns were taken into consideration in our investigation of the English-speaking patient JP.

As in several other cases reported in the neuropsychological literature (for a review see Shapiro & Caramazza, 2003a), JP's naming skills were uneven across grammatical classes. They were remarkably good with nouns but fairly poor with verbs. JP's accurate noun naming prompted our investigation of his noun production, specifically to see if noun stems and inflections were equally spared. Other tests were undertaken to determine the status of noun semantics and phonology in order to assess whether, as predicted by connectionist accounts, semantic and/or phonological deficits appeared along with deficits for stems or inflections.

As opposed to the case with nouns, JP was impaired at accessing the stems of verbs. This grammatical class deficit exhibited by JP allowed us to address two additional questions about inflectional processing. First, to what extent do problems of stem retrieval affect inflection production? An answer to this question may shed light on the form of interaction existing between processes of stem and inflection retrieval. Second, to what extent are there distinct inflectional processes for nouns and verbs? An answer to this question has potential implications for understanding the role of grammatical class in speech production. These two questions will be discussed in the final part of the paper.

The presentation of JP's data is organized as follows. We start by providing some background information about JP's neuropsychological deficit and brain lesion. Next, we report the data about nouns. Finally, we present data about verbs.

1. Case description

At the time of investigation, JP was a 76-year-old English-speaking male with 16 years of education. He held a Master's degree in graphic design and had worked in the audio-visual departments of several educational institutions. In 2004 he suffered a stroke affecting the superior division of the middle cerebral artery. A CT-scan made shortly after the stroke revealed encephalomalacia consistent with infarct affecting parts of the inferior frontal and precentral gyri (and underlying subcortical white matter) in the left hemisphere. Our investigation began six months after his stroke and continued for about seven months. JP's neurological condition remained stable during the investigation and a CT-scan following its conclusion showed that it was unchanged from before. (JP refused to have an MRI scan due to claustrophobia.)

Spontaneous speech was severely reduced showing the distinctive pattern of agrammatism. There was a marked decrease in the number of words produced, a predominance of nouns and frequent omissions of inflections and function words. These characteristics were quantified in an analysis of JP's narration of the Cookie Thief Picture (from Goodglass & Kaplan, 1972), which consisted of 24 words produced after several laborious attempts; 58% of the words were nouns, 21% verbs, and 21% function words. JP's spontaneous speech also exhibited characteristic features of dysarthria. His speech was slow and slurred and occasionally he required several attempts to complete a word.

Verbal short-term memory also appeared to be impaired. JP's digit span was abnormal with lists repeated forward (correct repetitions never exceeded 3 or 4 digits). Word reading was mildly impaired. In reading aloud, JP identified 220 of 239 words correctly (92%), showing no effects of regularity, length, concreteness or frequency. His errors in the reading aloud task consisted of phoneme substitutions (e.g., "grit" for *grid*), or deletions and additions of single or multiple phonemes. Repetition of nonwords was also impaired. He correctly repeated 43/60 (72%) nonwords presented auditorily. The majority of his errors (12/17) were lexicalization errors (e.g., *clake* → "click"). The remaining errors were single phoneme errors that resulted in nonwords (e.g., *durv* → "gurv"). JP's verbal short-term memory deficit could be the cause of his nonword repetition deficit, as it was reported for other neuropsychological cases (Caramazza, Miceli, & Villa, 1986; Shallice, Rumiati, & Zadini, 2000; Shallice & Warrington, 1977), although we cannot exclude the contribution of an impairment to non-lexical mechanisms for input–output transcoding of speech sounds, as proposed for some other cases (e.g., Jacquemot, Dupoux, & Bachoud-Lévi, 2007). JP's problems with verbal short-term memory, reading and nonword repetition were taken into account when designing the tasks included in our investigation.

We also assessed JP's written spelling to determine whether word inflections were similarly impaired in the written modality. Due to a right arm paresis subsequent to the stroke, JP had to write using the non-dominant left hand. Writing was effortful and often letters were ill formed. Nevertheless, some clear errors were observed. As in the examples *canal* → CHARINT or *giraffe* → GRANS, JP's errors were typically quite different from the word targets. Because of JP's frustration with using the non-dominant hand and uncertainties with scoring some of JP's letter errors, the investigation of written spelling was not pursued further.

In a previous study, we documented JP's problems in assigning thematic roles with verbs and spatial prepositions (Miozzo, Fischer-Baum, & Postman, 2008). When asked to describe events he often had difficulties in determining who did what to whom. For example, when presented with a picture of a man teaching a woman, he described it as "the woman teaches the man." Our data further indicated that these role reversal errors were not due to grammatical deficits or problems with understanding the meaning of verbs or spatial terms.

2. Noun processing

In this section we report JP's results in tests that assessed his production of noun stems and affixes as well as the availability of lexical and semantic information concerning nouns.

2.1. Noun lexical access

Stems, like other idiosyncratic word forms, need to be stored in the lexicon. We reasoned that if noun lexical representations are intact, not only noun stems but also other types of lexicalized information about nouns should be available. To investigate this, we tested two types of nouns that have unpredictable forms which need to be memorized: irregular plural nouns and derived nouns. A handful of English nouns take unpredictable plural forms like *oxen*, *teeth*, or *feet* that need to be memorized. The fact that more than one suffix can be used to generate derived nouns makes these forms unpredictable as well. An example is offered by English nouns derived from verbs, which are formed adding different suffixes, for example, *-ment* (*development*) or *-ion* (*action*). Access to noun stems was tested with Object Picture Naming, whereas the production of irregular plural nouns and derived nouns was tested with Word Elicitation. As in all the other tasks reported in our study, we analyzed the first complete responses produced by JP.

2.1.1. Object Picture Naming

JP orally named pictures of individual objects, for which single, zero-suffixed nouns were expected as responses. To assess JP's naming as accurately as possible, we only used picture sets with norms available from controls matched to JP for age and education: Boston Naming Task (Goodglass & Kaplan, 1972), Philadelphia Naming Task (Roach, Schwartz, Martin, Grewal, & Brecher, 1996), and the object picture sets from Snodgrass and Vanderwart (1980) and Zingeser and Berndt (1990). In all of these tasks, JP essentially produced the same nouns as controls (*z*s between −0.1 and +0.4; the results of the individual tasks are shown in Table 1). These findings demonstrate JP's preserved access to noun stems. The intactness of JP's noun vocabulary is further confirmed by the quality of JP's naming responses; his response to *umbrella* is an example: he commented, "It can also be a parasol or a bumbershoot." (A few number

Table 1
Tests of noun lexical access.

Task	Correct responses
Object Picture Naming	
Boston Naming Task	93% (56/60; z = +0.2)
Philadelphia Naming Task	95% (167/175; z = −0.1)
Snodgrass & Vanderwant's Picture Set	90% (234/260; z = +0.3)
Zingeser & Berndt's Noun Picture Set	100% (60/60; z = +0.4)
Word Elicitation	
Irregular plural nouns	97% (29/30)
Derived nouns	
From verbs (*to resign* → "resignation")	96% (48/50; z = −0.7)
Occupations (*to lobby* → "lobbyist")	98% (50/51; z = −0.7)

Table 2
Examples of phrases and sentences used to elicit different word forms.

Word form	Eliciting phrases/sentences	Target word
Irregular plural nouns	One mouse, two _	[*mice*]
Derived nouns		
a. From verbs	If I resign; I make a _	[*resignation*]
b. Occupation names	If I lobby; I am a _	[*lobbyist*]
Noun inflections		
a. Singular → plural	This is a grill; these are _	[*grills*]
b. Plural → singular	These are grills; this is a _	[*grill*]
Pseudonoun inflections		
a. Singular → plural	This is a plonk; these are _	[*plonks*]
b. Plural → singular	These are plonks; this is a _	[*plonk*]
Regular/irregular verb inflections		
a. Past tense, regular	Today I walk; yesterday I _	[*walked*]
b. Past tense, irregular	Today I sing; yesterday I _	[*sang*]
c. Past participle, regular	Today I walk; in the past I have _	[*walked*]
d. Past participle, irregular	Today I sing; in the past I have _	[*sung*]
Verb inflections varying for number/tense		
a. Singular → plural	This person grills; these people _	[*grill*]
b. Plural → singular	These people grill; this person _	[*grills*]
c. Past → present	Yesterday I grilled; today I _	[*grill*]
d. Present → past	Today I grill; yesterday I _	[grilled]
Pseudoverb inflections		
a. Singular → plural	This person plonks; these people _	[*plonk*]
b. Plural → singular	These people plonk; this person _	[*plonks*]

errors like *dinosaur* → "dinosaurs" were noticed in these tasks but were ignored here since we focused on stem retrieval.)

2.1.2. Word Elicitation

Examples of the sentences used to elicit irregular plural nouns and derived nouns are shown in Table 2. The experimenter presented the sentences aloud, which JP completed, producing the expected nouns (the same procedure was used in all the other elicitation tasks we administered). The Word Elicitation task for irregular plural nouns also included filler nouns with regular plurals (*dogs*, *chairs*) that were presented to introduce variation in the responses. Two types of derived nouns were employed: nouns derived from verbs (e.g., *to resign* → *resignation*), and occupation names derived from verbs (*to lobby* → *lobbyist*). Each of the types of derived nouns we tested could take at least two suffixes (see Table 3 for a full list of these suffixes). Responses were also collected for derived nouns from five age- and education-matched control participants. (Control subjects with similar characteristics were tested in some of the other tasks reported here.) JP was very accurate with both irregular plural nouns (29/30, 97%) and derived nouns (zs = −0.7; see Table 1 for a complete summary of the scores to derived nouns).

Table 3
Types of derived nouns and their suffixes tested with JP.

Type of derived nouns	Suffix
Derived from verbs	
to deploy → *deployment*	*-ment*
to act → *action*	*-tion*
to abstain → *abstinence*	*-ence*
to fail → *failure*	*-ure*
Occupation names (derived from verbs)	
to bake → *baker*	*-er*
to type → *typist*	*-ist*
to assist → *assistant*	*-ant*

Table 4
Tests of inflected nouns.

Task	Correct responses
Object Picture Naming	
Singular nouns	84% (84/100)
Plural nouns	83% (83/100)
Word Elicitation	
Singular nouns (*grills* → "grill")	73% (44/60)
Plural nouns (*grill* → "grills")	80% (48/60)
Total nouns	*77% (92/120)*
Singular pseudonouns (*plonks* → "plonk")	67% (31/46)[a]
Plural pseudonouns (*plonk* → "plonks")	81% (35/43)[a]
Total pseudonouns	*74% (66/89)*

[a] Lexicalization errors were excluded from analysis (see text for details).

2.2. Noun semantics

JP's accurate object naming provided a first indication that access to noun semantics was preserved. Noun semantics was tested more directly in a word-matching task that required fine-grained semantic discriminations. On each trial, JP saw three related written nouns (e.g., *hurricane*, *tornado*, *cyclone*) and indicated the two nouns that were more closely related (*cyclone* and *tornado* in our example). The written words were also read out loud by the experimenter to circumvent JP's reading difficulties. Although the task demanded access to detailed semantic representations, JP performed very accurately (74/77, 96%; z = −1.4).

2.3. Noun inflections

The production of singular and plural nouns was tested in two tasks: Object Picture Naming and Word Elicitation. In both tasks, the same nouns were tested in singular and plural forms following an ABBA design. We only tested the noun plural allomorphs -/*s*/ and -/*z*/ because they generate complex coda clusters with two or more consonants, unlike the epenthetic allomorph -/*es*/ (compare ha*nds*, with a final three-consonant coda, and flashe*s*, ending in a single consonant). To the extent that patients with phonological deficits find producing complex coda clusters to be particularly difficult, the allomorphs -/*s*/ and -/*z*/ offered a better opportunity to detect a phonological deficit. A summary of the data with noun inflections is shown in Table 4.

2.3.1. Object Picture Naming

Pictures showing either single objects (e.g., *one chair*) or pairs of identical objects (*two chairs*) were shown to have JP producing singular vs. plural nouns. We recorded only one picture misidentification (*flute* → "clarinet"), a finding confirming the availability of noun stems. However, JP's inflection production was impaired in this task, due to singular/plural confusions like *pear* → "pears" or *doors* → "door." Singular and plural noun inflections were produced with similar accuracy (correct responses: singular nouns = 84/100; plural nouns = 83/100). All of the inflection errors bore an incorrect *noun* inflection—that is, JP never appended verb inflections (as in the errors *doors* → "doored" or *grills* → "grilled").

2.3.2. Word Elicitation

Table 2 presents examples of the incomplete sentences that were used in order to elicit singular and plural nouns. Nouns were tested in lists that also contained pseudonouns, verbs and pseudoverbs with different inflections (these stimuli are described in Section 3). JP always produced noun stems correctly; his errors only occurred with inflections. With only one exception (*fund* → "foundation"), these errors were due to the selection of the incorrect *noun* inflection, as in the examples *broom* → "brooms" and *wagons* → "wagon." Five control participants made no inflectional errors in this task. Singular and plural nouns were produced by JP with similar accuracy (correct responses: singular nouns = 44/60, 73%; plural nouns = 48/60, 80%; $\chi^2 < 1$).

If a lexical deficit is not the cause of JP's impairment with noun inflections, inflection errors should appear also with pseudonouns, forms that, by definition, lack lexical entries. Separate lists were created to test pseudonouns in the elicitation task. The pseudonouns ($N = 50$) were identical to the nouns tested in the elicitation task in phoneme length and in that they took the allomorphs -/*s*/ or -/*z*/ in the plural (/pred*z*/, /bret*s*/). As described in Section 1, JP's nonword repetition was impaired and his incorrect responses were, for the most part, lexicalization errors resulting from substituting the nonwords with phonologically similar *existing* words (*clake* → "click"). Lexicalization errors were also observed in the elicitation task and with similar rates in singular and plural pseudonouns (4/50, 8% vs. 7/50, 14%). These errors were excluded from the analyses, as we were interested on the inflection of pseudowords. Given JP's problems in nonword repetition, we also ignored whether pseudonoun stems were correctly produced and only scored inflection accuracy. Inflections were similarly impaired with singular pseudonouns (31/46, 67% correct) and plural pseudonouns (35/43, 81% correct; $\chi^2 = 2.27$, $p > .10$). All inflection errors involved an incorrect *noun* inflection. No such errors were recorded from five control participants.

2.4. Concept numerosity

JP's errors with noun inflections could be explained if there were a semantic deficit that impaired the ability to identify concept numerosity on which morphological number is based. That is, JP's confusions between "dog" and "dogs" could stem not from the incorrect selection of noun inflections but from the incorrect encoding of whether there were one or more dogs. This hypothesis was tested in a spoken-word-matching task in which JP heard an object name either in its singular or plural form ("dog"/"dogs") and matched it to the picture showing one or two exemplars of that object. We reasoned that JP would fail in this task if his ability to identify concept numerosity were impaired. Contrary to this prediction, JP's responses were very accurate (117/120, 98%, correct). Responses remained similarly accurate when we used sentences of the form determiner + verb + noun ("This is a dog"/"These are dogs;" 117/120, 98% correct responses). In essence, the results of these matching tasks provided no indications of impaired concept numerosity.

2.5. Summary

JP's access to noun stems or other noun forms stored in the lexicon appeared to be intact (see result summary in Table 1). By contrast, JP's production of inflections of regular nouns was impaired and singular and plural forms were affected to similar degrees (see result summary in Table 4). The latter finding established that JP's deficit with inflections could not stem from a phonological deficit. One could have suspected that JP's noun inflection errors were caused by his verbal short-term memory deficit. Such an account predicts more errors for the longer and more memory taxing plural nouns—an expectation contradicted by JP's results. Finally, we can also rule out that a failure to accurately encode concept numerosity caused JP's errors with noun inflections. In the end, a deficit affecting the retrieval of noun inflections appeared to be the most likely cause.

Table 5
Tests of verb lexical access.

Task	Correct responses
Action Picture Naming (-ing verbs)	70% (21/30; $z = -9.4$)
Word Elicitation	
Irregularly inflected verbs *sing* → "sang"	68% (134/197; $z = -12.8$)
Regularly inflected verbs *walk* → "walked"	92% (181/197; $z = -19.9$)

3. Verb processing

The results of this section come from tests that assessed JP's production of verb stems and affixes as well as the availability of lexical and semantic information concerning verbs.

3.1. Verb lexical access

The tasks employed for testing lexical access with nouns were extended to verbs. In contrast to what we observed with nouns, lexical access was impaired for verbs (see data summary in Table 5).

3.1.1. Action picture naming

JP correctly produced 21/30 verbs (70%; $z = -9.4$) in response to action pictures from Zingeser and Berndt (1990). This score contrasted with JP's excellent performance in the same task with frequency-matched nouns (60/60 correct responses; $z = 0.4$). As was the pattern in other patients who have had selective verb deficits, JP's errors resulted from substituting a verb with a noun (*sitting* → "stool") or with light verbs, i.e., verbs that are less specific (e.g., *decorating* → "making").

3.1.2. Word Elicitation

Further evidence suggesting a lexical retrieval deficit with verbs was provided by JP's difficulties with irregular verb inflections. While the past tense and past participle of English verbs are typically obtained by appending the morpheme *-ed* to the verb stem, so-called "irregular verbs" defy this pattern and take idiosyncratic forms like *ran*, *stood*, or *made*. Irregular verb inflections have to be memorized and, consequently, are likely to fall prey to lexical deficits. Different sentences were used to elicit past tense and past participle forms (see examples in Table 2). Regular and irregular target verbs (from Miozzo, 2003) were matched for lemma and surface frequencies and had comparable phoneme length. JP's responses were more accurate with regular than irregular verb inflections, both in the past tense (93/100, 93% vs. 60/100, 60%; $\chi^2 = 30.28$, $p < .001$) and the past participle (88/97, 91% vs. 74/97, 76%; $\chi^2 = 7.33$, $p < .01$). He was significantly less accurate than control participants for both regular inflections ($z = -19.9$) and irregular inflections ($z = -12.8$).

3.2. Verb semantics

It has been proposed that for at least some patients, a semantic impairment specifically affecting the representations of actions and events was the underlying cause of their selective verb deficits (Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; McCarthy & Warrington, 1985). Whether JP's verb deficit had the same cause was tested with three tasks requiring detailed information of verb meaning. The first task was a replication of the word-matching task we described above with nouns. For example, given the verbs *contact*, *beat*, and *hit*, the last two were expected to be identified as the more closely related. JP's accuracy rate was comparable to controls' (124/127; 98%; $z = +0.2$). The second task, modeled from Kemmerer,

Table 6
Tests of inflected verbs.

Task	Correct responses
Word Elicitation—verbs	
Number change	
Singular, present *grill* → “grills”	87% (52/60)
Plural, present *grills* → “grill”	25% (15/60)
Tense change	
Present, plural *grilled* → “grill”	23% (14/60)
Past, plural *grill* → “grilled”	83% (50/60)
Present, singular *grilled* → “grills”	26% (16/60)
Past, plural *grills* → “grilled”	65% (39/60)
Total verbs	*52% (186/360)*
Word Elicitation—pseudoverbs	
Number change	
Singular, present *plonk* → “plonks”	84% (36/43)[a]
Plural, present *plonks* → “plonk”	74% (29/39)[a]
Total pseudoverbs	*79% (65/82)*

[a] Lexicalization errors were excluded from analysis (see text for details).

Tranel, and Barrash (2001), required JP to discriminate which of two verbs was more associated with a sensory/perceptual feature. For example, for the question “Which is louder?” the alternatives were *sweeping* and *vacuuming*. JP's choices were invariably correct (64/64). The third task required miming specific actions associated with a verb (“conducting”) or with a verb and an object (“playing the piano”). JP responded almost flawlessly (71/72 correct). In essence, there were no indications of deficient verb semantics from any of the demanding tasks we administered. A lexical deficit provided a better explanation of JP's impaired verb production.

3.3. Verb inflections

Word Elicitation tasks similar to those we described above with nouns have been used extensively in prior studies of patients exhibiting lexical deficits. The actual presentation of word stems would circumvent the problems of stem retrieval. In this way, the elicitation task offers the opportunity to investigate whether inflections are available even under conditions of lexical deficit. This rationale led us to use the elicitation task to test JP's verb inflections (see data summary in Table 6). We prepared different types of sentences to prompt three distinct verb inflections of the same verbs: (a) present, plural (*grill*), (b) present, 3rd person, singular (*grills*) and (c) regular past tense (*grilled*). Examples are shown in Table 2. As with nouns, we only tested verbs that bore single phoneme inflections (/*s*/, /*z*/, /*t*/, /*d*/). As described above, verbs with the different inflections were tested together with nouns.

JP's rate of correct responses was fairly low (186/360, 52%). The stem was incorrect in only 2/174 (1%) of the errors; in all the other cases it was the inflections that were incorrect. Control participants made very few inflectional errors and only with past-tense verbs (mean accuracy = 99%). JP performed unevenly across the different verb inflections, being comparatively less accurate with zero-affixation verbs (*grill*; 29/120, 24%) than with overtly affixed verbs (*grills* = 68/120, 57%; *grilled* = 89/120, 74%). We do not have an explanation for this pattern but suspect that (at least in part) it reflected JP's guesses about what inflections were included in each list and their frequencies. Of relevance here is that JP's errors with citation forms consisted of adding an affix, such as “grilled” or “grills” instead of *grill*. Thus, the inflection errors that JP produced most profusely showed increased rather than decreased phonological complexity and increased rather than decreased phoneme length.

Nouns were inflected by JP significantly more accurately than verbs (77% vs. 52%; $\chi^2 = 23.07$, $p < .001$). As in Shapiro, Shelton, and Caramazza (2000), some of the inflected words we tested were noun/verb homophones like (the) *grill*/(they) *grill*, or (the) *grills*/(she) *grills*. These homophones provided an ideal test case for assessing the effects of grammatical class independently from variations in phonology. JP was significantly worse with verb vs. noun inflections even in this better matched sample (correct responses: 67/120, 56% vs. 92/120, 77%; $\chi^2 = 9.05$, $p = .002$).

We also tested the inflection of pseudoverbs, that is, novel verbs like (they) *plonk* and (he) *plonks* that lack lexical entries. To compare nouns and verbs as closely as possible, identical pseudowords were tested in both grammatical classes (see examples in Table 2). Moreover, we applied the same scoring procedure used with pseudonouns. A comparable number of lexicalization errors were set aside with singular pseudoverbs (7/50, 14%) and plural pseudoverbs (11/50, 22%). Overall, inflection accuracy was equal to 65/82 (79%) and comparable between the two types of inflections we tested: citation forms (*plonk* = 29/39, 74%) and stem + s forms (*plonks* = 36/43, 84%; $\chi^2 = 1.09$, $p > .29$). Of note is the fact that inflection accuracy rates were comparable between pseudoverbs and pseudonouns (79% vs. 74%; $\chi^2 < 1$). The latter result was replicated even when only responses with correct stems were examined (pseudoverbs = 51/69, 74%; pseudonouns = 60/80, 75%; $\chi^2 < 1$), an analysis we conducted to ascertain that stem errors did not affect inflection choice.

3.4. Summary

JP's verb stem production was impaired, a deficit attributable to a lexical rather than a semantic deficit. Inflection production was impaired with verbs significantly more severely than with nouns. In contrast to the grammatical class effects observed with existing nouns and verbs, pseudonouns and pseudoverbs appeared to be impaired to equal degrees. The latter result ruled out that JP's more severe deficit with verb than noun inflections was due to the greater number of inflections taken by English verbs. If this were the reason, then we should also have observed a worse performance with pseudoverbs than with pseudonouns. Further implications of the effects of grammatical class and lexical status on inflection production will be discussed in the final part of the paper.

4. General discussion

JP demonstrated a striking dissociation with nouns: although he could retrieve the correct stems, he was impaired at producing inflections of regular nouns. JP's results also showed that noun inflection errors could not be attributed to a phonological deficit, verbal short-term memory impairment, or problems with concept numerosity. Instead, JP's results suggest a deficit specifically affecting the selection of noun inflections. Stems and inflections could still be assembled properly as there was no major phonological deficit that jeopardized this process.[1]

As discussed in the introduction, there is considerable agreement in the language sciences that stems and inflections are processed by partially distinct cognitive and neural mechanisms. This view clearly leads to the prediction that brain lesions can

[1] If a phonological deficit was not the primary cause of JP's inflectional errors, the phonological complexity of the stem should not be one of the factors determining his errors. This prediction was tested in a post hoc analysis of JP's errors due to inflection omission (e.g., *pants* → “pant”) in which we compared nouns and verbs whose stems had either *simple* codas formed by a single consonant (pe*t*) or *complex* codas comprising two consonants (pa*nt*). As a result of a phonological deficit, JP should be more likely to delete inflections when words have complex rather than simple stem codas. We examined responses to nouns and verbs in both elicitation and picture naming tasks. Inflection omission errors were observed with comparable frequency with these two types of words (complex coda words = 13/93, 14%; simple coda words = 21/265, 8%; $\chi^2 = 2.273$; $p > .13$). This result does not support the hypothesis that a phonological deficit underlies JP's inflectional errors.

give rise to deficits selectively affecting the production of stems or inflections. The errors produced by agrammatic patients and conduction aphasics, in which correct inflections occur in the context of incorrectly produced stems, have often been cited as evidence of a selective preservation of inflection processing. JP's noun production demonstrated a mirror-image deficit: a selective impairment for inflections. Together, the data from JP and those from agrammatism and conduction aphasia support the view that specialized mechanisms exist for stems and inflections.

Although current proposals agree that distinctive mechanisms are involved in the processing of stems and inflections, disagreement exists on the nature of these mechanisms. Views have polarized around two major accounts: connectionist accounts and words-and-rules accounts. As described in the introduction, connectionist architectures reject specialized mechanisms for stems or inflections—specialized mechanisms are only assumed for semantics and phonology. In a connectionist framework, selective impairments for stems and inflections could only be caused by semantic and/or phonological deficits. However, JP's data did not support this straightforward prediction: neither a semantic deficit nor a phonological one constituted a plausible explanation of his noun inflection errors. The very selective nature of JP's impairment appears to be problematic for connectionist accounts.

However, impairments as selective as those observed in JP would be expected under words-and-rules accounts. These accounts hold that inflections are processed by specialized mechanisms that are distinct from those concerned with semantic and phonological processing. Under these accounts, inflections can be impaired even if semantics and phonology are not. JP's results with nouns probably provide some of the clearest examples of deficits circumscribed to inflections. As reviewed in the introduction, problems with inflections have been described in other patients in whom semantic and/or phonological deficits have also been demonstrated. Evidence that inflection deficits occur independently of semantic and phonological deficits represents a critical finding for words-and-rules accounts.

Other aspects of JP's results fit nicely with some of the details of words-and-rules accounts. In particular, these accounts hold that inflections depend in part on combinatorial mechanisms operating on general properties of the language – "rules" – that apply universally. These combinatorial mechanisms should then apply not only to familiar words but also to newly coined words or, in experimental settings, to novel words (pseudowords). This naturally leads to the prediction that an inflection deficit should also extend to pseudowords. And indeed, JP performed strikingly similarly with nouns and pseudonouns in the elicitation task (see Table 4). Nevertheless, words-and-rules accounts also appear insufficiently detailed, in their current formulation, to explain other features of the deficit of JP (and similar patients). For example, words-and-rules accounts remain silent as to whether lexical entries are organized along grammatical categories and can give rise to deficits restricted to specific grammatical classes. Moreover, words-and-rules accounts do not specify to what extent morphological processes differ between language production and comprehension. Patients like JP provide critical evidence for constraining and further refining words-and-rules accounts.

Marslen-Wilson and Tyler (1997) documented an inflectional deficit that could not be explained by semantic or phonological impairments, though this was in a comprehension task. They tested two aphasic patients using an auditory priming paradigm in a lexical decision task. Unlike controls, these patients did not respond faster when verb stems were preceded by their past-tense inflections, as in the prime–target pair *jumped–jump*. By contrast, facilitation was observed when the prime was an irregularly inflected verb (as in *found–find*) or when prime–target pairs were related semantically (*swan–goose*) or phonologically (*gravy–grave*). Because semantic and phonological priming was similar between these patients and unimpaired controls, it is unlikely that either deficient semantic or phonological processing caused the anomalous priming pattern observed with regularly inflected verbs. A more plausible explanation would be a problem with inflection processing.

Unlike Marslen-Wilson and Tyler (1997) patients, JP appears to be able to comprehend inflected forms. When pointing to pictures of one or many objects in response to plural vs. singular nouns, JP performed extremely accurately (97% correct), a finding that indicates preserved inflection comprehension. In contrast to the patients described by Marslen-Wilson and Tyler (1997), JP's deficit appears to selectively involve the production of inflected forms. All together, JP's results ostensibly demonstrate the dissociability of inflection processing in input vs. output. The possibility exists that inflection comprehension was merely mildly impaired in JP and only more sensitive tasks like auditory priming could unveil a deficit of relatively minor severity. Alternatively, JP's results could have arisen because distinct neural structures are involved in the comprehension and production of word inflections, at least in part. Such a separation may reflect fundamental differences in the functioning of the neural structures involved with comprehension vs. production, differences that may comprise, among other things, stem/affix parsing vs. stem/affix assembly, or the interfacing with input auditory streams vs. motor areas coordinating speech articulation.

If a deficit selectively affecting inflection selection can account for JP's errors with the inflections of nouns, pseudonouns and pseudoverbs, it is nevertheless insufficient to explain why JP performed significantly worse with verb inflections and made frequent errors with verb stems and irregularly inflected verbs. We clearly need to posit a second deficit to explain JP's selective verb problems. The fact that JP's verb deficit affected stems and irregular inflections, forms that are both stored at the lexical level, strongly suggests a lexical deficit as the most likely cause of JP's selective problems with verbs. A lexical deficit has also been proposed for other patients whose impaired verb production could not be explained by a semantic deficit (Caramazza & Hillis, 1991; Rapp & Caramazza, 2002; Zingeser & Berndt, 1988). As in the case of JP, left frontal damage was the predominant cause of the verb deficits in patients (e.g., Bak, O'Donovan, Xuereb, Boniface, & Hodges, 2001; Cappa et al., 1998; Damasio & Tranel, 1993; Daniele et al., 1994; Hillis, Oh, & Ken, 2004).

If our hypothesis of a lexical deficit selectively affecting verb stems is correct, a question arising naturally is why the lexical retrieval of stems should affect inflections. This seems a reasonable possibility in English, where inflection selection depends in part on lexical information. A memory search is required to determine whether a verb should be regularly inflected (talked) or a lexicalized form (sang) should be produced instead. Lexical representations may contribute to this choice either by activating the proper inflection or by inhibiting the regular forms that otherwise would be produced as defaults (Pinker, 1991). Moreover, the phonological make-up of English stems determines allomorph choice. For example, choosing -/t/ instead of -/d/ or -/ed/ in the English past tense depends on the phonemes of the stem endings. Conditions that prevent stem retrieval would affect allomorph selection. In light of these facts of the English language, it seems possible that a lexical deficit could disturb the selection of verb inflections, as we indeed observed in JP.

The question of whether shared or distinct substrates underlie noun and verb inflections has been previously studied in patients with grammatical class deficits. A common finding of these studies was that patients with selective deficits for either nouns or verbs have parallel impairment for pseudoword inflections (Shapiro & Caramazza, 2003a, 2003b; Shapiro, Shelton, & Caramazza, 2000;

Tsapkini, Jarema, & Kehaya, 2002). For example, the problems that patient RC (Shapiro & Caramazza, 2003b) had with verb inflections also extended to pseudoverbs and the same held true with the noun deficit of patient JR (Shapiro et al., 2000). To account for the widespread deficits found in these patients, Shapiro et al. (2000) proposed an impairment to a morphological system whose functioning depends on grammatical class. The activation of grammatical class information (noun, verb, adjective) constrains inflection selection to forms appropriate for words of that specific class. Distinct networks support the processing of each grammatical class and their impairment would selectively affect the inflections of specific grammatical classes.

Unlike previous cases, JP's selective verb deficit did not extend to pseudoverbs. The lack of a grammatical effect with pseudowords is open to two possible explanations. One possibility is that the distinct neural networks that under Shapiro et al.'s (2000) account support the morphological processing of nouns and verbs were impaired to a similar extent in JP. This type of impairment would have prevented us from observing any differences between pseudonouns and pseudoverbs. Alternatively, there are different neural structures implicated in morphological processing, but only in some of them does grammatical class determine further fractionations within the neural organization. This account is compatible with recent findings from neuroimaging (Herholtz et al., 1996; Perani et al., 1999; Shapiro, Moo, & Caramazza, 2006; Tyler, Bright, Fletcher, & Stamatakis, 2004; Warburton et al., 1996) and rTMS (Cappelletti, Fregni, Shapiro, Pascual-Leone, & Caramazza, 2008; Shapiro, Pascual-Leone, Mottaghy, Gangitano, & Caramazza, 2001) that revealed multiple cortical loci in the left midfrontal gyrus and inferior frontal gyrus (Broca's area) that responded selectively to the morphological characteristics of words. However, only some of these areas responded preferentially to verbs rather than nouns. The fact that left frontal areas were damaged in JP gives some plausibility to the hypothesis that damage to neural structures supporting the morphological processing of both nouns and verbs was responsible for JP's inflection deficit. Damage to other neural structures sensitive to grammatical class would give rise to the selective deficits for noun or verb inflections observed in other patients. Clearly, more data are needed to adjudicate between the alternatives discussed here.

While JP's data support a words-and-rules account of inflectional processing, they are not consistent with the neurocognitive interpretation of the word-and-rule account proposed by Ullman et al. (1997). Under this account, deficits for irregular inflections result from damage to left temporal structures, while deficits for regular inflections would arise from damage to left-inferior-frontal regions. Contrary to this, JP showed a more severe deficit for irregular inflection following left frontal damage. JP is remarkably similar to prior reported cases of patients with selective deficits for verbs, who also demonstrated more severe impairments for irregular inflections following left frontal damage (Balaguer, Costa, Sebastián-Gallés, Juncadella, & Caramazza, 2004; Miozzo, Costa, Hernández, & Rapp, 2010; Shapiro & Caramazza, 2003a). However, there are also neuropsychological data consistent with Ullman's neurocognitive account. In some patients more severe deficits for irregular verb inflections resulted from left temporal lesions (Miozzo, 2003; Ullman et al., 1997). Further evidence suggesting an involvement of left temporal structures in the processing of irregular verb inflections has come from semantic dementia, a neurodegenerative pathologic process predominantly affecting temporal structures and which more severely impairs the processing of irregular inflections (Cortese, Balota, Sergent-Marshall, Buckner, & Gold, 2006; Patterson, Lambon Ralph, Hodges, & McClelland, 2001). Patients with left temporal lesions who handled irregular inflections poorly typically did not exhibit selective verb deficits. Moreover, in cases where these forms were tested, irregular inflections of nouns and verbs were demonstrated to be impaired in equal degrees (Miozzo, 2003; Miozzo et al., 2010; Miozzo & Gordon, 2005), unlike JP who showed a spared production of irregular noun plurals such as feet and oxen. Although the appearance of findings as divergent as these makes it plausible that distinct neural loci are critical in the processing of irregular inflections, the functional roles undertaken by each of these putative regions remain unclear. The retrieval of irregularly inflected forms is a comparatively more demanding process, as demonstrated by the longer response latencies obtained when normal speakers named these forms (Jaeger et al., 1996). Greater processing demand could also be the reason why patients failed with irregular inflections in particular. However, this can hardly be the only reason in light of results that have demonstrated greater impairments for regular forms (Marslen-Wilson & Tyler, 1997; Ullman et al., 1997), a pattern also replicated by JP with nouns. As observed by Shapiro and Caramazza (2003a), patients like JP who demonstrate selective verb deficits are problematic for the view that only temporal structures are involved in the processing of irregular inflections (Ullman, 2001). As we have seen, the data of such patients indicate that left frontal areas are also implicated in the processing of irregular forms. A clear-cut division of labor in which regular and irregular verbs are supported by frontal and posterior areas, respectively, appears to be an inaccurate account in view of the complexity of the neuropsychological findings.

5. Conclusions

Deficits selectively targeting inflections have remained elusive. JP showed such a deficit, but only with nouns. JP's selective deficit would have remained undetected had different grammatical classes not been thoroughly investigated. Our investigation was spurred by prior cases of grammatical class deficits and has proven once again that, as our knowledge of neuropsychological deficits has deepened, we can unveil further selective impairments and thus provide critical test cases for current theories. JP's inflectional deficit with nouns is predicted by a words-and-rules account of inflectional processing though it appears to be problematic for connectionist accounts. That JP's inflection deficit emerged in the context of relatively spared semantic and phonological processing suggests that inflection processing is relatively independent both functionally and neuroanatomically from processes associated with stems. But this is a limited autonomy because, as we have seen with JP's responses to verbs, a lexical deficit can also affect inflection production. The fact that inflection production emerges as an interactive process is certainly not surprising, given the variety of factors – syntactic, semantic and lexical – that jointly contribute to specifying the inflection that has to be selected at a specific point in time. Understanding the nature of such interactivity and its neural underpinning is one of the challenges for future research on morphology.

Acknowledgements

We would like to thank: Jeremiah Bertz, Gordy Rogers and Cristina Sanchez for their help in designing materials and testing JP and the control subjects, Argyle Hillis for consultation on the localization of the brain damage, Brenda Rapp for her helpful suggestions in interpreting the results, and JP and his family for graciously participating in hours of testing. This investigation was supported by a grant from the National Institutes of Health (NIH) grant DC-006242 given to the first author.

References

Albright, A., & Hayes, B. (2002). Modelling English past tense intuitions with minimal generalization. In M. Maxwell (Ed.), *Proceedings of the 2002 workshop on morphological learning*. Philadelphia, PA: Association for Computational Linguistics.

Allen, M., & Badecker, W. (2001). Morphology: The internal structure of words. In B. Rapp (Ed.), *The handbook of cognitive neuropsychology: What deficits reveal about the human mind/brain*. Hover, UK: Psychological Press.

Aronoff, M. (1994). *Morphology by itself*. Cambridge, MA: MIT Press.

Badecker, W., & Caramazza, A. (1991). Morphological composition in the lexical output system. *Cognitive Neuropsychology*, *8*, 335–368.

Badecker, W., & Caramazza, A. (1998). Morphology and aphasia. In A. Spenser, & A. M. Zwicky (Eds.), *Handbook of morphology* (pp. 390–405). Oxford: Blackwell Publishers.

Bak, T. H., O'Donovan, D. G., Xuereb, J. H., Boniface, S., & Hodges, J. R. (2001). Selective impairment of verb processing associated with pathological changes in Broadmann areas 44 and 45 in the motor neurone disease-dementia-aphasia syndrome. *Brain*, *124*, 103–120.

Balaguer, R., Costa, A., Sebastián-Gallés, N., Juncadella, M., & Caramazza, A. (2004). Regular and irregular morphology and its relationship with agrammatism: Evidence from two Spanish-Catalan bilinguals. *Brain and Language*, *91*, 212–222.

Buckingham, H. W., & Kertesz, A. (1976). *Neologistic Jargon Aphasia*. Amsterdam: Swets & Zeitlinger.

Butterworth, B., & Howard, D. (1987). Paragrammaticisms. *Cognition*, *26*, 1–37.

Caplan, D., Kellar, L., & Locke, S. (1972). Inflection in neologisms in aphasia. *Brain*, *95*, 169–172.

Caplan, D., Vanier, M., & Bakes, C. (1986). A case study of reproduction conduction aphasia. I. Word production. *Cognitive Neuropsychology*, *3*, 99–128.

Cappa, S. F., Binetti, G., Pezzini, A., Padovani, A., Rozzini, L., & Trabucchi, M. (1998). Object and action naming in Alzheimer's disease and frontotemporal dementia. *Neurology*, *50*, 351–355.

Cappelletti, M., Fregni, F., Shapiro, K., Pascual-Leone, & Caramazza, A. (2008). Processing nouns and verbs in the left frontal cortex: A transcranial magnetic stimulation study. *Journal of Cognitive Neuroscience*, *20*, 707–720.

Caramazza, A., & Hillis, A. E. (1991). Lexical organization for nouns and verbs in the brain. *Nature*, *349*, 788–790.

Caramazza, A., Ludanna, A., & Romani, C. (1988). Lexical access in inflectional morphology. *Cognition*, *28*, 297-232.

Caramazza, A., Miceli, G., & Villa, G. (1986). The role of the (output) phonological buffer in reading, writing and repetition. *Cognitive Neuropsychology*, *3*, 37–76.

Caramazza, A., Papagno, C., & Ruml, W. (2000). The selective impairment of phonological processing in speech production. *Brain and Language*, *75*, 428–450.

Clahsen, H. (1999). Lexical entries and rules of language: A multidisciplinary study of German inflections. *Behavioral and Brain Sciences*, *22*, 991–1060.

Cortese, M. J., Balota, D. A., Sergent-Marshall, S. D., Buckner, R. L., & Gold, B. T. (2006). Consistency and regularity in past-tense verb generation in healthy ageing. Alzheimer's disease, and semantic dementia. *Cognitive Neuropsychology*, *23*, 856–876.

Damasio, A. R., & Tranel, D. (1993). Nouns and verbs are retrieved with differently distributed neural systems. *Proceedings of the National Academy of Science of the United States of America*, *90*, 4957–4960.

Daniele, A., Giustolisi, L., Silveri, M. C., Colosimo, C., & Gainotti, G. (1994). Evidence for a possible neuroanatomical basis for lexical processing of nouns and verbs. *Neuropsychologia*, *32*, 1325–1341.

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

Gordon, P. (1985). Level-ordering in lexical development. *Cognition*, *21*, 73–93.

Hahn, U., & Nakisa, R. C. (2000). German inflections: Single route or dual route? *Cognitive Psychology*, *41*, 313–360.

Halle, M., & Marantz, A. (1993). Distributed morphology and the pieces of inflection. In K. Hale, & S. J. Keyser (Eds.), *The view from building 20* (pp. 111–176). Cambridge, MA: MIT Press.

Haspelmath, M. (2002). *Understanding morphology*. London: Arnold Publishers.

Herholtz, K., Thiel, A., Wienhard, K., Pietrzyk, U., von Stockhausen, H. M., Karbe, H., et al. (1996). Individual functional anatomy of verb generation. *Neuroimage*, *3*, 185–194.

Hillis, A. E., Oh, S., & Ken, L. (2004). Deterioration of naming nouns versus verbs in primary progressive aphasia. *Annals of Neurology*, *55*, 268–275.

Jackendoff, R. (2002). *Foundations of language*. New York, NY: Oxford University Press.

Jacquemot, C., Dupoux, E., & Bachoud-Lévi, A. C. (2007). Breaking the mirror: Asymmetrical disconnection between the phonological input and output codes. *Cognitive Neuropsychology*, *24*, 3–22.

Jaeger, J. J., Lockwood, A. H., Kemmerer, D. L., Van Valin, R. D., Murphy, B. W., & Khalak, H. G. (1996). A positron emission tomographic study of regular and irregular verb morphology in English. *Language*, *72*, 451–497.

Joanisse, M. F., & Seidenberg, M. S. (1999). Impairments in verb morphology after brain injury: A connectionist model. *Proceedings of the National Academy of Science of the United States of America*, *96*, 7592–7597.

Kemmerer, D., Tranel, D., & Barrash, J. (2001). Patterns of dissociations in the processing of verb meanings and brain-damaged subjects. *Language and Cognitive Processes*, *16*, 1–34.

Marslen-Wilson, W., & Tyler, L. K. (1997). Dissociating types of mental computation. *Nature*, *387*, 592–594.

Marslen-Wilson, W., & Tyler, L. K. (1998). Rules, representations, and the English past tense. *Trends in Cognitive Sciences*, *2*, 428–435.

Marslen-Wilson, W. D., & Tyler, L. K. (2007). Morphology, language and the brain: The decompositional substrate for language comprehension. *Philosophical Transactions of the Royal Society: Biological Sciences*, *362*, 823–836.

McCarthy, R., & Warrington, E. K. (1985). Category specificity in an agrammatic patient: The relative impairment of verb retrieval and comprehension. *Neuropsychologia*, *23*, 709–727.

Menn, L., & Obler, L. K. (1990). *Agrammatic aphasia*. Philadelphia, PA: John Benjiamins.

Miceli, G., Capasso, R., & Caramazza, A. (2004). The relationship between morphological and phonological errors in aphasic speech: Data from a word repetition task. *Neuropsychologia*, *42*, 273–287.

Miozzo, M. (2003). On the processing of regular and irregular forms of verbs and nouns: Evidence from neuropsychology. *Cognition*, *87*, 101–127.

Miozzo, M., Costa, A., Hernández, M., & Rapp, B. (2010). Lexical processing in the bilingual brain: Evidence from grammatical/morphological deficits. *Aphasiology*, *24*, 262–287.

Miozzo, M., Fischer-Baum, S., & Postman, J. (2008). Knowing what but not where. Impaired thematic roles and spatial language. *Cognitive Neuropsychology*, *25*, 853–873.

Miozzo, M., & Gordon, P. (2005). Facts, events, and inflection: When language and memory dissociate. *Journal of Cognitive Neuroscience*, *17*, 1074–1086.

Mirkovic, J, MacDonald, M., & Seidenberg, M. S. (2005). Where does gender come from? Evidence from a complex inflectional system. *Language and Cognitive Processes*, *20*, 139–167.

Patterson, K., Lambon Ralph, M. A., Hodges, J. R., & McClelland, J. L. (2001). Deficits in irregular past-tense verb morphology associated with degraded semantic knowledge. *Neuropsychologia*, *39*, 709–724.

Perani, D., Cappa, S., Schnur, T., Tettamanti, M., Collina, S., Rosa, M., et al. (1999). The neural correlates of verb and noun processing: A PET study. *Brain*, *122*, 2337–2344.

Pinker, S. (1991). Rules of language. *Science*, *253*, 530–533.

Pinker, S. (1999). *Words and rules: The ingredients of language*. New York, NY: Basic Books.

Plaut, D. C., & Gonnerman, L. M. (2000). Are non-semantic morphological effects incompatible with a distributed connectionist approach to lexical processing? *Language and Cognitive Processes*, *15*, 445–485.

Plunkett, K., & Marchman, V. (1993). From rote learning to system building: Acquiring verb morphology in children and connectionist nets. *Cognition*, *48*, 21–69.

Rapp, B., & Caramazza, A. (2002). Selective difficulties with spoken nouns and written verbs: A single case study. *Journal of Neurolinguistics*, *15*, 373–402.

Roach, A., Schwartz, M. F., Martin, N., Grewal, R. S., & Brecher, A. (1996). The Philadelphia Naming Test: Scoring and rationale. *Clinical Aphasiology*, *24*, 121–133.

Rumelhart, D. E., & McClelland, J. L. (1986). On learning the past tenses of English verbs. In J. L. McClelland, D. E. Rumelhart, & PDP Research Group (Eds.), *Parallel distributed processing: Explorations in the microstructure of cognition. Vol. 1: Foundations*. Cambridge, MA: MIT Press.

Schreuder, R., & Baayen, R. H. (1995). Modelling morphological processing. In L. Feldman (Ed.), *Morphological aspects of language processing*. Hillsdale, NJ: Lawrence Erlbaum.

Seidenberg, M. S., & Gonnerman, L. M. (2000). Explaining derivational morphology as a convergence of codes. *Trends in Cognitive Sciences*, *4*, 353–361.

Semenza, C., Butterworth, B., Panzeri, M., & Ferreri, T. (1990). Word formation: Evidence from aphasia. *Neuropsychologia*, *28*, 499–502.

Shallice, T., Rumiati, R. I., & Zadini, A. (2000). The selective impairment of the phonological output buffer. *Cognitive Neuropsychology*, *17*, 517–546.

Shallice, T., & Warrington, E. K. (1977). Auditory-verbal short-term memory impairment and conduction aphasia. *Brain and Language*, *4*, 479–491.

Shapiro, K., & Caramazza, A. (2003a). Grammatical processing of nouns and verbs in left frontal cortex? *Neuropsychologia*, *41*, 1189–1198.

Shapiro, K., & Caramazza, A. (2003b). Looming a loom: Evidence for independent access to grammatical and phonological properties in verb retrieval. *Journal of Neurolinguistics*, *16*, 85–111.

Shapiro, K. A., Moo, I. R., & Caramazza, A. (2006). Cortical signatures of noun and verb production. *Proceedings of the National Academy of Sciences*, *103*, 1644–1649.

Shapiro, K. A., Pascual-Leone, A., Mottaghy, F. M., Gangitano, M., & Caramazza, A. (2001). Grammatical distinctions in the left frontal cortex. *Journal of Cognitive Neuroscience*, *13*, 1–8.

Shapiro, K., Shelton, J., & Caramazza, A. (2000). Grammatical class in lexical production and morphological processing: Evidence from a case of fluent aphasia. *Cognitive Neuropsychology*, *17*, 665–682.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Human Learning & Memory*, *6*, 174–215.

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. *The Quarterly Journal of Experimental Psychology*, *57A*, 745–765.

Tsapkini, K., Jarema, G., & Kehaya, E. (2002). A morphological processing deficit in verbs but not in nouns: A case study in a highly inflected language. *Journal of Neurolinguistics*, *15*, 265–288.

Tyler, L. K., Bright, P., Fletcher, P., & Stamatakis, E. A. (2004). Neural processing of nouns and verbs: The role of inflectional morphology. *Neuropsychologia*, *42*, 512–523.

Ullman, M. T. (2001). A neurocognitive perspective on language: The declarative/procedural model. *Nature Reviews Neurosicence*, *2*, 717–726.

Ullman, M. T., Corkin, S., Coppola, M., Hickok, G., Growdon, J. H., Koroshetz, W. J., et al. (1997). A neural dissociation within language: Evidence that the mental dic-

tionary is part of declarative memory, and that grammatical rules are processed by the procedural system. *Journal of Cognitive Neuroscience*, *9*, 266–276.
Warburton, E, Wise, R., Price, C., Weiller, C., Hadar, U., Ramsay, S., et al. (1996). Noun and verb retrieval by normal subjects: Studies with PET. *Brain*, *119*, 159–179.
Wilshire, C. E., & McCarthy, R. A. (1996). Experimental investigation of an impairment in phonological encoding. *Cognitive Neuropsychology*, *13*, 1059–1096.
Zingeser, L., & Berndt, R. (1988). Grammatical class and context effects in a case of pure anomia: Implications for models of language production. *Cognitive Neuropsychology*, *5*, 473–516.
Zingeser, L., & Berndt, R. (1990). Retrieval of nouns and verbs in agrammatism and anomia. *Brain and Language*, *39*, 14–32.