# ON NOUNS, VERBS, LEXEMES, AND LEMMAS: EVIDENCE FROM THE SPONTANEOUS SPEECH OF SEVEN APHASIC PATIENTS

**Davide Crepaldi[§], Chiara Ingignoli[§], Ruggero Verga[^], Antonella Contardi[$], Carlo Semenza[@*] and Claudio Luzzatti[§$]**

§ Department of Psychology, University of Milano-Bicocca, Italy

^ Salvini General Hospital, Passirana Rehabilitation Unit, Passirana di Rho, Italy

$ Maugeri Foundation, IRCCS, Montescano Scientific Institute, Montescano, Italy

@ Department of Neuroscience, University of Padova, Italy

* S. Camillo Hospital, IRCCS, Lido di Venezia, Italy

**SHORT TITLE:** Noun-verb dissociation in connected speech

**Corresponding author:**

Davide Crepaldi,

Department of Psychology, University of Milano-Bicocca
Piazza Ateneo Nuovo, 1
20126, Milano, Italy.

Phone number: +39 02 64483840
Fax number: +39 02 64483706
E-mail: davide.crepaldi1@unimib.it

## ABSTRACT

*Background*. Although disproportionate impairment of noun or verb retrieval has been described on the basis of the evidence from several aphasic cases since the mid 1980s, with different theoretical frames being proposed to account for noun-verb dissociation, very few studies have dealt with this dissociation in spontaneous speech.

*Aims*. The objectives of this study were to investigate (i) whether the dissociation also emerged in connected speech, and (ii) whether the analysis of patients' narratives could shed light on the functional damage underlying their grammatical-class-specific impairment.

*Methods and Procedures*. Two non-fluent verb-impaired patients, two fluent verb-impaired patients and three fluent noun-impaired patients participated in this study. Their noun-verb dissociation was preliminarily assessed through a picture naming task, following which their spontaneous speech collected and analysed using a single-case approach, taking into consideration both lexical productivity (as indicated by the number of different tokens produced by the patients) and lexical diversity (as indicated by the number of different types and stems used by the patients).

*Outcomes and results*. Non-fluent verb-impaired patients tended to produce a lower proportion of verb types than unimpaired control participants, as opposed to fluent verb-impaired patients, who produced a normal verb rate in their spontaneous speech on all counting procedures. One out of three fluent noun-impaired patients produced a lower proportion of noun tokens, types, and stems compared to normal speakers.

*Conclusions*. The data presented in this paper indicate that noun-verb dissociation as assessed in picture naming tasks might not emerge in spontaneous speech and indicates the need for the inclusion of a lemma level in models of word production that aims at explaining grammatical-class-specific impairments in people with aphasia.


**Keywords:** grammatical class, noun-verb dissociation, spontaneous speech, lexical diversity, type, token, stem, lemma, lexeme.

## ACKNOWLEDGMENTS

The study was supported by research grant n° 2003107555/001 from the *Ministero dell'Università e della Ricerca Scientifica* (MIUR; *Italian Ministry of Education, University and Scientific Research*). Preliminary results of this study were presented at the 7th *Science of Aphasia Conference,* Alghero (Italy), September 7-12, 2006, and at the 44th Annual Meeting of the *Academy of Aphasia*, Victoria (Canada), October 15-17, 2006. We thank Mirella Frustaci, Graziella Ghirardi and Paola Saletta for their help in collecting the spontaneous speech samples.

# INTRODUCTION

People with aphasia may suffer from disproportionate naming impairment of either verbs or nouns (e.g., McCarthy and Warrington, 1985; Zingeser and Berndt, 1988). The noun-verb dissociation has been interpreted (i) as an effect of damage to specific subsets of conceptual knowledge, i.e., sensory-visual semantic features (which are more relevant for the semantic representation of nouns) vs. functional semantic features (more relevant for the semantic representation of verbs; Bird, Howard, & Franklin, 2000), (ii) as a by-product of the noun-verb imageability mismatch (Bird et al., 2000) and (iii) as a lexical phenomenon arising either in the input or output phonological or orthographic lexicons (e.g., Hillis & Caramazza, 1995) or at a more central lexical-syntactic store (e.g., Berndt, Mitchum, Haendiges, & Sandson, 1997). This latter dichotomy between input and output, phonological and orthographic lexicons on the one hand, and a more central lexical-syntactic store on the other hand, reflects a popular distinction in psycholinguistics between *lexemes*, orthographic or phonological word representations, and *lemmas*, modality-independent word representations containing syntactic information such as grammatical gender for nouns or thematic structure for verbs (Levelt, Roelofs, & Meyer, 1999). Models of speech production that make use of the lemma-lexeme dichotomy assume that the first step in lexical selection is lemma selection; speakers would first retrieve the grammatical properties of the intended word (e.g., in the case of verbs, their argument structure) and, only after an individual lemma has been selected, they would retrieve its phonological word form (i.e., the corresponding lexeme). Lemma selection is thus necessary for lexeme selection, but not vice versa; lemma retrieval can be accomplished without the intended word being ultimately articulated (as in the tip-of-the-tongue phenomenon; e.g., Levelt, 1993).

An important distinction between lemma-based and lexeme-based accounts of noun-verb dissociation is related to where grammatical class is represented within the word production system. Scholars who consider grammatical-class specific impairments as due to lexeme damage suggest that nouns and verbs are stored separately in the phonological lexicon (e.g., Rapp & Caramazza, 2002); on the contrary, authors who believe that noun-verb dissociation emerges at the lemma level usually assume grammatical class to be

represented here, with no distinction between nouns and verbs at the lexeme level (e.g., Crepaldi, Aggujaro, Arduino, Zonca, Ghirardi, Inzaghi, Colombo, Chierchia, & Luzzatti, 2006).

Damage to the *lemma* level and the *lexeme* level may be particularly hard to disentangle, even though modality-by-grammatical-class simple and double dissociations have indeed been used in the literature to address similar issues. Rapp and Caramazza (2002) described a patient (KSR) who was predominantly impaired at retrieving nouns in spoken production and verbs in written production and concluded that noun-verb dissociation could not be due to semantic damage in this patient; in fact, conceptual damage should cause an identical noun-verb dissociated pattern across modalities, as both written and oral production are sub-served by the same conceptual system. Although this is certainly correct, it is not sufficient to conclude that KSR's damage lies at the lexical level. Indeed, this patient's modality-by-grammatical-class dissociation may have emerged from grammatical-class-specific damage to the semantic-lexical interface, i.e., an impairment to the connections between the semantic system and the peripheral lexicons (see Figure 1a). The same consideration can be applied to the *lemma-lexeme* dichotomy, if the model of speech production described by Levelt and colleagues (1999) is assumed. As the lemma level sub-serves both oral and written lexical production exactly as does the semantic system (see Figure 1b), a KSR-like performance can of course be used to conclude that the lemma level is preserved, but does not imply that the grammatical-class-specific impairment has to be placed at the lexeme level (Figure 1b). In this paper we consider the analysis of patients' connected speech as a further potential tool to investigate the functional impairment underlying noun-verb dissociation, focusing in particular on the distinction between *lemma* and *lexeme* damage.

(FIGURE 1 ABOUT HERE)

### *Noun-verb dissociation and spontaneous speech in people with aphasia*

Although several studies have reported poor verb production by agrammatic patients in narrative speech (e.g., Guasti and Luzzatti, 2002; Saffran, Berndt, & Schwartz, 1989; Thompson, Lange, Schneider,

& Shapiro, 1994; Zingeser and Berndt, 1988), neurolinguistic studies conducted so far on the noun-verb dissociation have focused quite exclusively on formal tasks like picture naming, sentence completion and word naming, and have generally not assessed the dissociation in spontaneous speech.

Marshall, Chiat, Robson and Pring (1996) reported the case of a patient, RV, who suffered from a left CVA and consequently developed jargonaphasia. This patient was more successful in retrieving verbs than nouns in a picture naming task; the authors also studied RG's connected speech using a picture description task and focusing their analysis on the number and the type of errors made by the patient on nouns and verbs. The results showed more errors on nouns than on verbs in RG's connected speech, even if (i) it is not completely clear how errors were detected and classified (e.g., it is not always obvious which is the intended target in patients' speech) and (ii) no specific statistical analysis was carried out to contrast RG's performance on nouns and verbs (nor RG vs. normal speakers).

A different approach was taken by Druks and Carroll (2005), who reported the case of a fluent aphasic patient (DOR) with a better performance on nouns than verbs in picture naming. These authors investigated the distribution of words belonging to different grammatical classes in DOR's spontaneous speech. Importantly, Druks and Carroll did not use a picture description task to elicit speech -- i.e., a condition in which patient's production is still constrained by some external input and is heavily influenced by her picture naming ability --, but analysed samples of spontaneous speech, where DOR was (at least potentially) free to make use of her whole lexical-semantic space. The results indicated poor lexical production of verbs; as in Marshall et al.'s study though, no statistical comparison was carried out (i) between verbs and nouns, and (ii) between DOR and a normal speakers control sample.

Bastiaanse and Jonkers (1998) conducted a group study on eight verb-impaired anomic and eight verb-impaired agrammatic patients, explicitly comparing their performance on an object/action picture naming task to their verb production in spontaneous speech. Both agrammatic and anomic patients performed better with nouns than with verbs on the picture naming task. Both groups showed a lower than normal verb type/token ratio in spontaneous speech: the verb impairment detected in picture naming also emerged in the patients' spontaneous speech as a reduced lexical diversity of the verbs produced. However,

the type/token ratio did not correlate with the percentage of verbs correctly retrieved in the picture naming task: the authors considered this result to be a consequence of a trade-off between lexical richness and morpho-syntactic accuracy. Although it provides interesting evidence on patients' verb production in spontaneous speech, Bastiaanse and Jonkers's study has some limitations. Firstly, it considers the patients' performance only at group level, while there is clear evidence that different functional damage may underlie verb impairment in the individual patients, even for those suffering from the same type of aphasia (see above); consequently, a single-case series approach appears to be required when approaching this issue. Moreover, as in the studies reported above, the authors analysed the verb production of people with aphasia suffering from disproportionate verb impairment, but did not investigate the production of nouns by noun-impaired individuals.

*Lexical productivity and lexical diversity in spontaneous speech*

In the light of the results obtained by Bastiaanse and Jonkers (1998) and by a number of other researchers in the past years (e.g., Harris Wright, Silverman, & Newhoff, 2003), in the present study we considered different measures for lexical productivity, which is reflected by the overall number of words (tokens) produced by patients in their spontaneous speech, and lexical diversity, which refers instead to the number of different lexical forms (types) used by patients in their narrative samples (see Templin, 1957; Semenza, 1999). It must be considered, however, that a high number of types may merely reflect the production of several different inflected forms of the same lexical entry - 'borrowed' and 'borrows' are in fact different types, but both words are inflected forms of the same lemma, 'to borrow'; this could result in fluent patients having a higher type production than non-fluent patients simply as a result of their preserved morphological abilities (e.g., Butterworth, 1979; Luzzatti and De Bleser, 1996). A more precise measure of the dimension of the patients' lexicon can be obtained from the number of different lexical entries produced in speech, irrespective of the inflection (the *stem* count). Therefore in the present study we analysed the number of tokens, types and stems separately, as it is possible that the different functional damage underlying noun-verb dissociation might let this phenomenon emerge with some count methods, but not

with others.

### *Aim of the study*

As the studies conducted so far do not provide clear-cut evidence on this issue, the first objective of the present study was to assess the emergence of the noun-verb dissociation in the spontaneous speech of aphasic brain-damaged patients. Moreover, we aimed at evaluating whether the analysis of spontaneous speech could shed light on the functional damage underlying the dissociated performance shown by patients in single-word retrieval, with particular focus on the distinction between *lemma*, *lexeme* and *lemma-lexeme interface* impairment. While severe *lemma* damage and *lexeme* impairment are expected to result in poor production of nouns/verbs also in connected speech, patients who are impaired at the *lemma-lexeme interface* are likely to benefit from the syntactic-semantic context characterizing spontaneous speech: this may facilitate lexical retrieval (particularly of verbs) so that verb- or noun-specific impairment may not emerge in connected speech.

## Materials and Methods

### *Subjects*

Seven Italian mild-to-moderate patients with aphasia participated in the study, which was conducted in compliance with institutional research standards for human research and in accordance with the Helsinki declaration. Each of these patients suffered from a cerebral damage, which occurred 6 to 30 months before their spontaneous speech and their ability to name pictures of objects and actions were evaluated; the locus of their brain lesions is reported in Table 1. All the patients were right handed; their mean age and education were 36 and 11 years respectively (see Table 1). Type and severity of the aphasia were assessed by means of the Italian version of the Aachen Aphasia Test (AAT: Luzzatti, Willmes, & De Bleser, 1996): five patients suffered from fluent aphasia (three from Wernicke's aphasia, two from anomic aphasia), while two patients suffered from agrammatic non-fluent aphasia. Patients' language impairment was considered

to be fluent when the output was abundant; articulation, prosody and phrase length were normal, sentences had a complex syntactic structure, but contained interruptions, agreement errors and/or substitutions of function words. On the contrary, aphasia was classified as non-fluent when the output was sparse, phrases were short, words were produced with effort, little prosody or impaired articulation and sentence structure was simplified as a consequence of the lack of subordinate clauses and the frequent omission of function words. All the patients included in this study were clear of severe post-lexical phonological impairments (e.g., had normal or mildly impaired performance in nonword repetition).

The preliminary condition for inclusion in the study was a predominant noun or verb impairment in single word retrieval; the potential participants were tested for this impairment with a picture naming task of 30 nouns and 40 verbs matched for subjective age of acquisition (3.9 ± 1.2 vs. 3.9 ± 1.3, on a 1-to-9 scale; see Colombo & Burani, 2002), familiarity (5.6 ± .9 vs. 5.6 ± .8, on a 1-to-7 scale) and word frequency (6.6 ± 12 vs. 12.0 ± 17, in number of occurrences per 500,000 words; De Mauro, Mancini, Vedovelli, & Voghera, 1993). An attempt was also made to match verbs and nouns for imageability, but, as usual, this proved to be impossible since, with very few exceptions, verbs were given lower imageability ratings than nouns (6.3 ± .3 vs. 4.6 ± .5, on a 1-to-7 scale; see Luzzatti, Raggi, Zonca, Pistarini, Contardi, & Pinna, 2002). Four patients (two fluent and two non-fluent agrammatic) performed significantly better on naming objects rather than actions, while the opposite pattern of impairment was found in the remaining three patients (all suffering from fluent aphasia; see Table 1). As in virtually all the noun-verb dissociated cases reported in the noun-verb literature, the performance on the less impaired grammatical class was significantly worse than that obtained by normal controls (see Table 1; Shallice, 1989).

(TABLE 1 ABOUT HERE)

### *Analysis of the picture naming data*

The performance of the patients on the picture naming task was analysed through a multivariate Logistic Regression Analysis (McCullagh & Nelder, 1983), where accuracy on each item was predicted by

grammatical class, spoken word frequency and imageability. We started the analysis from a full factorial model (i.e., a model that includes all main effects and interactions) and progressively simplified it by removing effects that (i) were non-significant (at a p level of .05) and (ii) did not determine a significant loss of explanatory power when removed from the model (as assessed through a Chi-square test on the difference between model fits). Logistic Regressions were carried out independently for each patient; synonyms of the standard target words (e.g., 'hound' for 'dog') were considered as correct, as were self corrections provided within 3 seconds from the presentation of the stimulus[1]. The aim of this analysis was twofold. On the one hand, we were interested in assessing the noun-verb dissociations partialling out the effects of lexical-semantic covariates. On the other hand, we aimed at testing frequency and imageability effects (along with their interaction with grammatical class) as it was possible that it could provide converging evidence on the functional level of the cognitive impairment underlying the dissociation; frequency effects are in fact thought to arise predominantly in the phonological output lexicon (Andrews, 1992; Levelt & Wheeldon, 1994; Monsell, Doyle, & Haggard, 1989), while imageability effects can be considered to reflect more central (mainly semantic) processing (Bates, Burani, D'Amico, & Barca, 2001; Bird, Howard, & Franklin, 2000; Coltheart, Patterson, & Marshall, 1987). We also carried out a qualitative analysis of the errors made by the patients in the picture naming task.

*Narrative sample collection*

Patients' spontaneous speech was collected in accordance with the AAT diagnostic procedure, i.e., through a semi-structured interview on how their language problems started, on their linguistic difficulty at the moment of the interview, on their family, their work and their hobbies. Patients were allowed to express themselves as freely as possible; in compliance with the AAT guidelines (Luzzatti et al., 1996), the interviewer intervened only to redirect patients when the conversation veered outside the topic or when patients could not communicate their thoughts appropriately.

*Narrative sample analysis*

Narratives were transcribed following the CHILDES guidelines (MacWhinney, 2000) and a sample of about 300 words was considered for each patient, according to the principles described by Semenza, Panzeri and Re (1989; see also Vermeulen, Bastiaanse, & van Wageningen, 1989). The samples collected for the two non-fluent agrammatic patients FC and LZ were somewhat shorter (143 and 209 words respectively) since they could not produce a 300-word narrative sample in a reasonable amount of time. Any locution that could be interpreted as an echolalic phenomenon was removed from the narrative and excluded from the analyses, as were perseverations, incomplete words, and neologisms.

Moreover, following Semenza et al.'s (1989) procedure, we did not break up sentences at the end of the samples; therefore the length of the narratives varied slightly even for fluent patients.

The following values were calculated for each patient's speech sample: (i) number of nouns, (ii) number of content verbs (the only type of verbs tested in picture naming tasks, e.g., 'to read'), (iii) number of function (closed-class) verbs (never assessed in picture naming tasks, e.g., 'has' in 'Paul has done a cake'). As in several cases verb impairment has been reported to be associated with more general difficulties in retrieving words with relevant syntactic role, we also considered (iv) the overall number of closed-class items and (v) the overall number of open-class items. In computing these values, we considered as open-class items all nouns, content (lexical) verbs, adjectives and adverbs that are derived from adjectives. Closed-class words included copulae, auxiliaries, articles, prepositions, numerals, pronouns, possessives, adverbs not derived from adjectives (e.g., *'quasi'*, 'almost'), and conjunctions.

Three different counting procedures were used:

i. *Token count*: All tokens were counted irrespective of whether they had already been produced either in the base form or in any morphologically related form (e.g., the sample 'eat', 'eating' and 'eat' includes 3 verb tokens);

ii. *Type count*: the number of types was computed by counting only the first occurrence for each token (e.g., the sample 'eat', 'eating' and 'eat' include 2 verb types);

iii. *Stem count*: only the first occurrence of each individual lexical entry was considered, irrespective of the inflection, making this variable a morphology-free index of lexical diversity (e.g., the sample 'eat', 'eating' and 'eat' include just 1 verb stem).

All the variables used in the present study were computed independently by the first and the second author: disagreement emerged just in a handful of cases and was refereed by the last author.

### *Statistical methods*

The data obtained by the patients with aphasia were compared to those reported by Semenza et al. (1989; see Table 2) for a sample of 40 normal speakers of different age (20 participants were between 18 and 30 years of age, while 20 were between 55 and 65) and educational levels (20 participants had less than 8 years of education, while 20 had more than 13 years of education). As Semenza et al.'s study found no significant difference in the profiles according to age, normative data were collapsed across this variable to increase statistical power.

To comply with the norms reported in Semenza et al.'s study (1989), the number of instances in each class was divided by the total number of instances in the sample; this was done separately for tokens (i.e., the rate of verb tokens is obtained by dividing the number of verb tokens by the total number of tokens), types (e.g., the rate of verb types is obtained by dividing the number of verb types by the total number of types) and stems (e.g., the rate of verb stems is obtained by dividing the number of verb stems by the total number of stems).

(TABLE 2 ABOUT HERE)

As individual patients with the same dissociation may suffer from different underlying cognitive damage, results were analyzed with a multiple single-cases approach. In order to compare the profiles of the single patients with the normal speakers' performance, we used the modified *t*-value described in Sokal and Rohlf (1995; see also Crawford and Howell, 1998), which makes use of a more reliable estimate of the

population variance compared to the classical *t* or *z* scores[2]. As these latter values, modified *t*-scores are informative on where a patient lies with respect to the statistical distribution of the same variable in the population (e.g., a *p*-value of .04 indicates that 4% of the population would obtain this or a lower/higher score on that variable).

As it was possible to set specific hypotheses regarding the patients' performance (noun-impaired patients were expected to produce *less* nouns than normal speakers and verb-impaired patients were expected to produce *less* content verbs than normal speakers), one-tailed probability values were calculated for nouns and content verbs. The same directional hypotheses could not be formulated for function verbs (as the picture naming task did not assess the patients' performance in this respect) or closed-class and open-class items (as both nouns and verbs belong to the latter category), so two-tailed probability values were considered in these analyses (see Table 4 and 5). As open- and closed-class words are in complementary distribution (and thus a higher/lower proportion of one category necessarily implies a lower/higher proportion in the other), only one set of analyses was performed for these data. Given that poor production of function words in speech is one of the defining features of non-fluent aphasia, non-fluent patients were clearly expected to produce a lower rate of closed-class elements than normal controls. Although this allowed us to consider one-tailed probability values, two-tailed values were eventually used in this analysis to ensure a homogeneous statistical approach to all the patients considered in the study.

## RESULTS

### *Picture naming data*

As reported in the Materials and Methods section, the picture naming performance of each individual patient was analysed through a Logistic Regression Analysis where the effect of grammatical class was considered together with those of spoken word frequency and imageability; this analysis allowed us to evaluate noun-verb dissociation partialling out the effect of co-varying lexical-semantic variables and to obtain some potentially useful information on the functional locus of the aphasic patients' impairment.

The results of the Logistic Regression Analyses are illustrated in Table 3. The effect of grammatical class is significant in all patients, meaning that noun-verb dissociation persisted even after having partialled out the effects of word frequency and imageability. Spoken word frequency emerged as a significant performance predictor in five out of the seven patients considered in this study; the significance of this predictor did not correlate with either type of aphasia (one in two non-fluent patient was sensitive to frequency, as were four in five fluent patients) or the most impaired grammatical class (three out of four verb-impaired patients were sensitive to frequency, as were two out of three noun-impaired patients). The interaction between grammatical class and word frequency approaches significance in patient DM; this seems to reflect the fact that higher values of spoken frequency determined a higher probability of success in verb production (the regression coefficient was positive, 1.37, when verbs were analysed independently), but a lower probability of success in noun production (the regression coefficient was negative, -.19, when nouns were analysed independently). Imageability did not play any role in the picture naming performance of the patients entering this study; this factor was included in the final model for patient GDP (because it contributed significantly to the general fit of the model), but was far from being significant.

(TABLE 3 ABOUT HERE)

The distribution of the errors made by the patients in the picture naming task is described in Table 4. Semantic substitutions were fairly frequent in all patients. On the contrary, phonemic errors resulting in nonwords (e.g., /fot/ for /pot/) were extremely rare since patients with moderate-to-severe post-lexical phonological impairment were not included in the study. Critically, no phonemic errors resulting in existing words (e.g., /dot/ for /pot/) were observed.

(TABLE 4 ABOUT HERE)

*Spontaneous speech*

The profiles obtained by the patients entering this study are described in Tables 3, 4, and 5, where the raw number of items produced, their percentage in the speech sample, and their corresponding *t* and *p* values are reported for nouns and open-class verbs (Table 3); closed-class verbs (Table 4); open- and closed-class items (Table 5). A table summing up the entire set of raw data collected in this study is provided in Appendix A; the complete list of open-class verbs and nouns produced by each patient is instead available from the authors on request, together with the spoken frequency value for each stem.

(TABLE 5 ABOUT HERE)

(TABLE 6 ABOUT HERE)

(TABLE 7 ABOUT HERE)

The agrammatic patients LZ and FC have rather similar profiles as far as verb production is concerned, as they both showed a normal proportion of verb tokens and stems, and a reduced rate of verb types very close to significance. On the other hand, both patients showed a higher rate of nouns in their speech as revealed by the token, type and stem counts, which appears to be the consequence of their very poor production of function verbs and closed-class words in general (see Tables 4 and 5).

On the contrary, the connected speech of the fluent verb-impaired patients UB and MC does not show any reduction in verb proportion; these patients show a higher-than-normal verb rate in their token, type and stem counts.

The profiles of the fluent noun-impaired patients DM and PV were quite similar to each other; their noun rate did not differ significantly from that in normal speakers, whereas their content verb token and type figures were significantly higher than those shown by the control sample. The fact that DM had a normal proportion of open-class verb stems clearly shows that her higher rate of verb tokens and types was mostly due to different inflected forms of the same lexical entries; this is less clear for PV, whose verb stem

figure approaches significance ($p = .15$). Both patients also produced a normal rate of function verbs, both in terms of tokens and types (see Table 4). Finally, DM's and PV's distribution of closed-class and open-class words is similar to that characterising the control sample (see Table 5).

Although GDP's speech was comparable to DM's and PV's with regards to (i) his high proportion of content verb tokens and types, and (ii) the balancing between open- and closed-class items, this patient did show a reduced proportion of nouns in his spontaneous speech, both in terms of lexical productivity and in terms of lexical diversity.

## DISCUSSION

Most of the studies reporting on aphasic patients suffering from grammatical-class-specific lexical impairment have focused exclusively on formal tasks, and have not tested noun-verb dissociation in spontaneous speech samples; in the few cases in which it was done (Bastiaanse and Jonkers, 1998), the authors limited their analysis to verb production by verb-impaired patients. Altogether, there is no general picture of whether grammatical-class-specific impairments also arise in spontaneous speech and how abnormal patterns in connected speech correspond to the same phenomenon in picture naming. In the present study we addressed these issues by analysing narrative samples in a wide range of patients with aphasia, i.e., non-fluent verb-impaired patients, fluent verb-impaired patients and fluent noun-impaired patients.

### *The role of the type of aphasia*

The patients suffering from disproportionate verb impairment in the picture naming task fell into two groups when their spontaneous speech was analysed: while the non-fluent patients tended to produce a lower rate of content verb types (but not tokens or stems) as compared to the control sample, the patients with fluent aphasia had no difficulty in producing content verbs in their speech (see Figure 2a and b). As far as the three noun-impaired patients are concerned, two of them showed a normal noun rate in their speech, while in one case the noun-specific impairment highlighted by the picture naming task also emerged in

spontaneous speech (Figure 2c).

(FIGURE 2 ABOUT HERE)

*Non-fluent verb-impaired patients*

The non-fluent verb-impaired patients who participated in this study produced a low rate of content verb types; both LZ's and FC's performance was just outside the significance threshold in this respect. These results replicate those of Bastiaanse and Jonkers (1998), who concluded that the verb-specific impairment highlighted by the picture naming task also emerged in connected speech as reduced lexical diversity.

The stem count considered in the present study allows us to qualify this conclusion better. In fact, LZ and FC showed a content verb proportion in their connected speech that was similar to that of normal speakers as far as stems – rather than types – were concerned; in other words, if the contribution of different inflected forms of the same lexical entry (e.g., 'speak' and 'spoke', which are counted as separate types, but not as separate stems) is excluded, lexical diversity does not seem to be different from that of healthy individuals. Thus a verb-specific impairment emerges in these non-fluent patients only as an inferior production of different inflected verb forms: LZ and FC produced a normal rate of verb lexical entries (as suggested by the stem count), produced some form of these verbs at a normal rate (as suggested by the token count), but showed very low inflectional variety (type count).

It is difficult to draw a conclusion regarding the emergence of verb-specific impairment in non-fluent patients' connected speech on the basis of these data. On the one hand, there is indeed an indication of poor verb production in the patients' speech, i.e., the low rate of content verb types; moreover, the reduced inflectional variety highlighted by this variable is certainly sensitive to grammatical class (the noun type rate is even higher than that shown by normal speakers). On the other hand, the lexical impairment revealed by the picture naming task is lexical-semantic – not morphological – in nature, so it would be expected to emerge in the token count or, more likely, in the stem count. Also, considering that (i) the inflectional

impairment could be specific for verbs because in Italian this class has an inflectional system that is far more complex than that of nouns[3] and (ii) morphological problems generally characterise the spontaneous speech of agrammatic non-fluent patients (independently of whether they show any verb impairment in picture naming), there is insufficient evidence to state that the reduced verb-type ratio observed in the data truly reflects the grammatical-class-specific impairment emerging in the picture naming task.

Alternatively, it could be argued that unique functional damage is responsible for both the verb impairment emerging in picture naming and the poor inflectional diversity characterising verb production in spontaneous speech. Poor inflectional diversity of verbs is consistent with the Tree Pruning Hypothesis of verb impairment in Agrammatism suggested by Friedmann (2000), according to which a morpho-syntactic impairment would prevent verbs from moving to the relevant position of the syntactic tree. However, the Tree Pruning Hypothesis also predicts a lower-than-normal rate of verb tokens and stems in connected speech, as it states that aphasic patients do not produce verbs at all if these cannot be moved to the position of the syntactic tree - the head of the Tense Phrase - where they are eventually inflected; our data clearly do not confirm this prediction.

*Fluent verb-impaired patients*

As the non-fluent verb-impaired patients, UB and MC did not produce a lower proportion of verb tokens than the control participants; they even showed a tendency toward a higher-than-normal verb token rate instead. For what concerns type production, the performance pattern that emerged in fluent verb-impaired patients is radically different to that shown by non-fluent verb-impaired patients; not only UB and MC were no worse than normal speakers in their verb lexical diversity, but they also showed a higher-than-normal verb type rate in their spontaneous speech. This pattern cannot be interpreted as due to the fluent patients' spared ability to generate different inflected forms of the same lexical entry (see Footnote 2) since both patients also have a normal verb-stem rate in their speech samples. On the whole, the verb-specific impairment that emerged in these patients when they were tested with the picture naming task does not affect at all their spontaneous speech: the fluent verb-impaired patients included in this study

tend to produce a higher proportion of verb tokens, types and stems than normal speakers during conversation.

### *Fluent noun-impaired patients*

Two of the three patients suffering from noun impairment in the picture naming task did not show a similar deficit in connected speech: both DM and PV have a normal proportion of noun tokens, types and stems in their connected speech, thus mirroring the performance of the verb-impaired patients who did not show any specific difficulty in producing verbs in their connected speech. GDP revealed a different pattern: his noun rate was indeed lower than that of healthy individuals as far as tokens, types and stems are concerned. He is the only patient in this study whose impairment profile in the picture naming task was similar to that of his connected speech. It is interesting to note that the distinction between the patients who did not show any noun impairment in their spontaneous speech (DM and PV) and the patient who did (GDP) reflects the distinction between anomic and Wernicke's fluent aphasia. Even if this association does not seem to be generalisable to *all* noun-impaired patients, it might be taken as an indication that the functional damage underlying noun-verb dissociation might differ in these two groups of patients.

### *The functional locus of the lesion*

As we have discussed above, six out of the seven dissociated patients participating in this study did not appear to suffer from any grammatical-class-specific impairment in their connected speech; this seems to contrast the hypothesis of functional damage being localised at the lexeme level, as the repertoire of phonological word forms used in picture naming and spontaneous speech is obviously the same. This is also suggested by the analysis of the performance obtained by the patients in the picture naming task; in particular, no formal paraphasia (e.g., /dot/ for /pot/) was observed, and phonemic errors were very rare in general. This is certainly related to the inclusion criteria adopted in this study (none of the aphasic patients considered here had moderate-to-severe phonological problems); nevertheless, it indicates that lexeme representations were relatively spared in these patients.

The question remains as to whether a functional impairment lying at a more central level of processing could be more compatible with the results that emerged in this study. Let us suppose, for example, that a grammatical-class-specific impairment prevents the patients from activating lexeme representations from a (relatively) unimpaired lemma level (see Figure 3). With this type of functional damage, patients would in fact be expected to perform poorly in a picture naming task: they would successfully access the target lemma (i.e., grammatical class and syntactic features), but would not be able to retrieve its phonological word form. On the contrary, in line with the suggestions made by Crepaldi and colleagues (2006), the richer syntactic and communicational context characterising spontaneous speech and the presence of sentence frames determining a syntactically structured linguistic environment may boost the activation of the preserved lemma-level information during conversation, resulting in easier access to the phonological forms. This context-mediated lemma-boost mechanism could facilitate the patients' word retrieval in connected speech as compared to isolated word retrieval. In more formal terms, the lemma node of, e.g., the verb GIVE, $<X_{agent}, Y_{theme}, Z_{recipient}>$ might be only poorly activated in a standard single-word-retrieval testing condition and therefore might be unable to activate the lexeme node of the same verb */giv/*. Spontaneous speech provides several cues to act as primes for the activation of this representation; these are either internal (e.g., the semantic information flowing down from the sentence preparation stage, *X gave Y to Z* in our example) or external (e.g., an explicit question from the interviewer like "*who did that to you?"*, which may prime the thematic structure, $<who_{agent}, that_{theme}, you_{recipient}>$, no matter what the verb "did" referred to in the question). This may boost the activation of the lemma node GIVE through mechanisms that are similar to those highlighted in the extensive literature documenting syntactic priming (e.g., Pickering and Branigan, 1998). Of course, the phenomenon applies only if the lemma-level information is relatively preserved; if the cerebral damage has severely impaired the lemma system, this latter is likely to be insensitive to any priming condition[4], which is in line with the fact that verb production is very poor (if not entirely absent) in the spontaneous speech of more severe agrammatic patients. It is important to specify that we are not referring here to direct cueing provided by the interviewer; we are rather referring to the fact that conversation normally proceeds through structured sentences and thus provides numerous syntactic

cues (implicit and explicit) that may act at a semantic-syntactic level to facilitate word retrieval.

A similar mechanism might be brought into action for noun production, even if admittedly nouns play a less crucial syntactic role than verbs and the lemma-level information is less important for noun than for verb retrieval (e.g., Crepaldi et al., 2006). In fact, verb lemma representations contain information on the argument structure of the verbs (see Levelt et al., 1999), a feature that essentially defines the verb itself (see, e.g., Chomsky, 1981; Grimshaw, 1990; Luzzatti and Chierchia, 2002); by contrast, no information represented at the lemma level has similar importance in defining the grammatical class of nouns[5].

(FIGURE 3 ABOUT HERE)

An alternative account of the dissociation between picture naming and connected speech in the fluent verb-impaired patients might refer to the different functional knowledge required by verb production in the two tasks. There is growing evidence suggesting that verb representation in the human linguistic system has two different aspects, one specifically referring to the action plan represented by the verb (which is strictly related to the verb argument structure) and one specifying more subtle semantic aspects related to manner, for example differentiating to 'climb' and 'to clamber', or 'to crawl' and 'to creep' (e.g., Breedin and Martin, 1996; Laiacona and Caramazza, 2004); one might suggest that these two functional aspects of verb representation are differently involved in picture naming and spontaneous speech, with the former task specifically relying on manner information and the latter predominantly calling for thematic information. However, although there is no doubt that picture naming and connected speech production are based upon different sets of cognitive processes (with a number of steps in common), it is not clear why manner aspects should be crucial in picture naming, where the pictures used refer to the “most typical” representation of the action denoted by the verb. Moreover, thematic information has been shown to be significantly called upon in picture naming, as agrammatic patients have been demonstrated to be more error prone when naming transitive than intransitive verbs (e.g., Thompson et al., 1997; Luzzatti et al., 2002). Finally, this account of the dissociation between picture naming and spontaneous speech is only tenable when it applies to separate

patients (one suffering from specific damage to manner information – and thus performing poorly at picture naming – and one suffering from specific damage to thematic information – and thus producing fewer verbs in connected speech); however, in the present data the dissociation emerges principally within patients (e.g., UB, MC).

The account based on the lemma-lexeme interface impairment would therefore seem to be preferable to an interpretation of the results centred on the difference between argument structure and manner information; however, this is not, by any means, the only possible account for the dissociation between picture naming and spontaneous speech. If we focus on what these data reveal about noun and verb representations, the evidence presented in this study appears to favour models of lexical production that include a lemma level over those that do not. This conclusion is based on the following consideration: neither the semantic system nor the phonological lexicon seems to be differently involved in picture naming tasks and in conversation; as a consequence, any impairment involving either of these levels should have a similar impact on the two testing conditions. Specific impairments for grammatical class constitute no exception; thus lexical production models that only assume a semantic system and a phonological lexicon will have difficulty in accounting for noun- or verb-specific impairments that emerge exclusively in either picture naming or spontaneous speech, unless they call extra-lexical (e.g., conversational or pragmatic) factors into play. On the contrary, data suggest that the lexical-syntactic information stored at the lemma level is sensitive to the syntactically structured environment characterising conversation (but not picture naming; e.g., Crepaldi et al., 2006); therefore, even if the specific mechanisms in operation are different from those suggested in this Discussion (i.e., do not involve priming of lemma-level information), dissociations between picture naming and spontaneous speech can certainly be explained *within the lexical system*.

### *Token, type and stem counts*

As we noted in the Introduction, much research has highlighted that lexical productivity and lexical diversity may dissociate in aphasia. The data reported in the present study confirm the importance of

considering different measures of lexical production in spontaneous speech; although token, type and stem counts appear to be quite consistent overall, the underproduction of verbs characterizing non-fluent verb-impaired patients only emerged in the type count, while the overproduction of content verbs shown by noun-impaired fluent patients was only detected in the token and in the type count.

## CONCLUSIONS

Notwithstanding the considerable effort made in the last twenty years to improve understanding of the aphasic grammatical-class-specific lexical impairments, it is still not clear whether these deficits also emerge in spontaneous speech. The analysis of the speech samples of four verb-impaired and three noun-impaired aphasic patients suggests that:

(i) disproportionate lexical impairment of nouns or verbs emerging in picture naming tasks may also emerge in the patients' connected speech; however, contrary to some results reported so far, this does not appear to be the rule.

(ii) A separate analysis of the patients' token, type and stem production is important in order to assess the emergence of grammatical-class-specific impairment in spontaneous speech.

(iii) Our data did not indicate any direct relationship between noun-verb dissociation in spontaneous speech and type of aphasia; however, this latter factor correlates quite well with the noun/verb and the open-class/closed-class word distribution in the patients' connected speech.

(iv) The dissociation between picture naming and spontaneous speech seems to indicate that the functional damage underlying noun-verb dissociation is not located at the lexeme level (i.e., the phonological output lexicon). Although this conclusion cannot be generalized to all dissociated patients, it favours models of speech production that discriminate between a lemma and a lexeme level of processing in the lexicon.

# REFERENCES

Andrews, S. (1992). Frequency and neighborhood effects on lexical access: Lexical similarity or orthographic redundancy? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 234–254.

Bastiaanse, R. & Jonkers, R. (1998). Verb retrieval in action naming and spontaneous speech in agrammatic and anomic aphasia. *Aphasiology*, *12*, 951-969.

Bates, E., Burani, C., D'Amico, S., & Barca, L. (2001). Word reading and picture naming in Italian. *Memory & Cognition*, 29, 986-999.

Berndt, R. S., Mitchum, C. C., Haendiges, A. N., & Sandson, J. (1997). Verb retrieval in aphasia. 2. Relationship to sentence processing. *Brain and Language*, 56, 107-137.

Bird, H., Howard, D., & Franklin, S. (2000). Why is a verb like an inanimate object? Grammatical category and semantic category deficits. *Brain and Language*, *72*, 246-309.

Breedin, S. D., & Martin, R. C. (1996). Patterns of verb impairment in aphasia: An analysis of four cases. *Cognitive Neuropsycholy*, 13, 51-91.

Butterworth, B. (1979). Hesitation and the production of verbal paraphasias and neologisms in jargon aphasia. *Brain and Language*, *8*, 133-161.

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology*, 14, 177-208.

Chomsky, N. (1981). *Lectures on Government and Binding*. Dordrecht: Foris.

Colombo, L. & Burani, C. (2002). The influence of age of acquisition, root frequency and context availability in processing nouns and verbs. *Brain and Language*, 81, 398-411.

Coltheart, M., Patterson, K. E., & Marshall, J. C. (1987). Deep dyslexia since 1980. In M. Coltheart, K. E. Patterson, & J. C. Marshall, *Deep Dyslexia*. London: Routledge & Kegan Paul.

Crawford, J.R & Howell, D.C. (1998). Comparing an individual's test score against norms derived from small samples. *The Clinical Neuropsychologist*, 12, 482-486.

Crepaldi, D., Aggujaro, S., Arduino, L.S., Zonca, G., Ghirardi, G., Inzaghi, M.G., Colombo, M., Chierchia, G., & Luzzatti, C. (2006). Noun-verb dissociation in aphasia: The role of imageability and functional locus of the lesion. *Neuropsychologia*, *44*, 73-89.

Druks, J. & Carroll, E. (2005). The crucial role of tense for verb production. *Brain and Language*, *94*, 1-18.

Friedmann, N. (2000). Moving verbs in agrammatic production. In R. Bastiaanse & J. Grodzinsky (Eds.), *Grammatical Disorders in Aphasia: A Neurolinguistic* Perspective. London: Whurr.

Grimshaw, J. (1990). *Argument Structure*. Cambridge: MIT Press.

Guasti, M.T. & Luzzatti, C. (2002). Syntactic breakdown and recovery of clausal structure in agrammatism. *Brain and Cognition*, *48*, 385-391.

Harris Wright, H., Silverman, S.W., & Newhoff, M. (2003). Measure of lexical diversity in aphasia. *Aphasiology*, *17*, 443-452.

Hillis, A., & Caramazza, A. (1995). Representation of grammatical knowledge in the brain. *Journal of Cognitive Neuroscience*, *7*, 369-407.

Laiacona, M., & Caramazza, A. (2004). The noun/verb dissociation in language production: Varieties of causes. *Cognitive Neuropsycholy*, 21, 103-123.

Levelt, W.J.M. (1993). Lexical selection, or how to bridge the major rift in language processing. In Beckmann, F. & Heyer, G. (Eds.), *Theorie und Praxis des Lexikons*. Berlin: De Gruyter.

Levelt, W.J.M., Roelofs, A., & Meyer, A.S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*, 1-75.

Levelt, W. J. M. & Wheeldon, L. (1994). Do speakers have a mental syllabary? *Cognition*, 50, 239–269.

Luzzatti, C. & Chierchia, G. (2002). On the nature of selective deficits involving nouns and verbs. *Italian Journal of Linguistics*, 14, 43-71.

Luzzatti, C. & De Bleser, R. (1996). Morphological processing in Italian agrammatic speakers: Eight experiments in lexical morphology. *Brain and Language*, *54*, 26-74.

Luzzatti, C., Raggi, R., Zonca, G., Pistarini, C., Contardi, A., & Pinna, G.D. (2002). Verb-Noun double

dissociation in aphasic lexical impairments: the role of word frequency and imageability. *Brain and Language, 81*, 432-444.

Luzzatti, C., Willmes, K, & De Bleser, R. (1996). *Aachener Apahsie Test: versione italiana (II edizione)*. Firenze: Organizzazioni Speciali.

Mac Whinney, B. (2000). *The CHILDES Project: Tools for Analyzing Talk*. 3rd Edition. Mahwah, NJ: Lawrence Erlbaum Associates.

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

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

Monsell, S., Doyle, M. C., & Haggard, P. N. (1989). Effects of frequency on visual word recognition tasks: Where are they? *Journal of Experimental Psychology: General*, 118, 335–339.

Pickering, M.J. & Branigan, H.P. (1998). The Representation of Verbs: Evidence from Syntactic Priming in Language Production. *Journal of Memory and Language*, 39, 633-651.

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

Saffran, E.M, Berndt, R.S., & Schwartz, M.F. (1989). The quantitative analysis of agrammatic production: Procedure and data. *Brain and Language*, *37*, 440-479.

Semenza, C. (1999). Lexical semantic disorders in aphasia. In G. Denes & L. Pizzamiglio (Eds.) *Handbook of Neuropsychology*. London: Erlbaum.

Semenza, C., Panzeri, M., & Re, S. (1989). Eloquio spontaneo: categorie grammaticali. Prospettive per la clinica dei deficit lessicali. *Acta Phoniatrica Latina, 11*, 329-340.

Shallice, T. (1989). *From Neuropsychology to Mental Structure*. Cambridge: Cambridge University Press.

Sokal, R. R. & Rohlf, J. F. (1995). *Biometry*. San Francisco, CA: W.H. Freeman.

Templin, M.C. (1957). *Certain language skills in children, their development and interrelationship*. Minneapolis: University of Minnesota Press.

Thompson, C.K., Lange, K.L., Schneider, S.L, & Shapiro, L.P. (1997). Agrammatic and non brain damaged subjects' verb and verb argument structure production. *Aphasiology*, 11, 473–490.

Vermeulen, J., Bastiaanse, R., & van Wageningen, B. (1989). Spontaneous speech in aphasia: a correlational study. *Brain and Language*, *36*, 252-274.

Zingeser, L.B. & Berndt, R.S. (1988). Grammatical class and context effects in a case of pure anomia: Implications for models of language processing. *Cognitive Neuropsychology*, *5*, 473-516.

## FOOTNOTES

1. The overall rate of self corrections was .04 (22/490); however, only 10 of the 22 repairs (2% of all responses) were produced within 3 seconds from the presentation of the stimulus and were thus considered as correct.

2. The formula used to calculate the modified t value as suggested by Sokal and Rohlf (1995) is as follows:

$$t = \frac{X_1 - \bar{X}_2}{s_2\sqrt{N_2 + \frac{1}{N_2}}}$$

where $X_1$ represents the individual's score, $X_2$ is the mean of the normative sample, $s_2$ is the standard deviation of the normative sample, and $N_2$ represents the normative sample size.

3. The same verb stem generates more than 40 different inflected forms differing on three dimensions (person, tense, and aspect), while nouns can only appear either in their singular or their plural form.

4. For evidence on the absence of priming effects when a piece of information is severely impaired see for example Marslen-Wilson and Tyler (1997).

5. Note that nouns do sub-categorize complements, but this happens only exceptionally, for example in the case of abstract deverbal nouns (e.g. *destruction*) whose argument structure percolates from the corresponding verb.

# TABLES

Table 1. Age, education, aetiology, lesion site (as assessed through CT scan), time post-onset, type of aphasia and performance obtained on the preliminary picture naming task. Pt, patient's initials; Ed., education; V(H), vascular (haemorrhagic); V(I), vascular (ischemic); TBI, traumatic brain injury; L, left; F, frontal; T, temporal; inf, inferior; P, parietal; sup, superior; O, occipital; AT, aphasia type; NFlu, non-fluent aphasia; Flu(W), fluent Wernicke's aphasia; F(A), fluent anomic aphasia; Diss, type of dissociation. The probability values associated with the noun-verb direct comparison (last column) are obtained through a chi-square test. All rates of correct responses on nouns or verbs are individually lower than those obtained by normal controls ($p<.01$).

| | | | | | | | | Picture naming task | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Nouns | Verbs | Ns vs. Vs |
| Pt | Age | Ed. | Aetiology | Lesion site | Months post-onset | AT | Diss | % correct | % correct | p |
| LZ | 36 | 15 | V(H) | L FT | 24 | NFlu | N>V | 70 | 38 | <.001 |
| FC | 21 | 15 | V(I) | L FT | 6 | NFlu | N>V | 87 | 30 | <.001 |
| UB | 49 | 8 | V(I) | L inf P | 30 | Flu (W) | N>V | 87 | 48 | <.001 |
| MC | 35 | 8 | TBI | L sup T and inf P | 13 | Flu (W) | N>V | 73 | 8 | <.001 |
| DM | 18 | 11 | TBI | L mid and inf T | 12 | Flu (A) | V>N | 13 | 38 | <.005 |
| GDP | 53 | 8 | V(I) | L inf T and O | 11 | Flu (W) | V>N | 13 | 40 | <.005 |
| PV | 42 | 13 | V(H) | L inf T and O | 18 | Flu (A) | V>N | 13 | 58 | <.001 |

Table 2. Percentages of nouns, content verbs, function verbs, open-class items and closed-class items obtained by normal speakers (Semenza et al., 1989).

| | | |
|---|---|---|
| Nouns | Tokens | 18.25 ± 3.05 |
| | Types | 23.87 ± 2.99 |
| | Stems | 27.36 ± 3.68 |
| Content verbs | Tokens | 14.57 ± 1.82 |
| | Types | 20.68 ± 2.46 |
| | Stems | 17.26 ± 2.89 |
| Function verbs | Tokens | 4.55 ± 1.89 |
| | Types | 3.64 ± 1.37 |
| | | |
| Closed-class items | Tokens | 60.22 ± 3.16 |
| | Types | 44.33 ± 3.44 |
| | Stems | 43.01 ± 4.32 |
| Open-class items | Tokens | 39.78 ± 3.16 |
| | Types | 55.57 ± 3.34 |
| | Stems | 56.99 ± 4.32 |

Table 3. Regression coefficients (Coef.) and *p* values associated with (a) the main effect of grammatical class, (b) the main effect of lexical-semantic covariates, and (c) the interaction between grammatical class and lexical-semantic covariates, as revealed by a Logistic Regression Analysis. Empty cells refer to effects that were removed from the model because they did not contribute to the overall fit of the model. GC, grammatical class; SWF, spoken word frequency; Ima, imageability.

| | (a) GC | | (b) Covariates | | | | (c) Interactions | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | SWF | | Ima | | SWF | | Ima | |
| | Coef. | p | Coef. | p | Coef. | p | Coef. | p | Coef. | p |
| LZ | -1.22 | .01 | | | | | | | | |
| FC | -2.77 | <.001 | 1.30 | .01 | | | | | | |
| UB | -1.92 | <.005 | 1.38 | <.005 | | | | | | |
| MC | -3.43 | <.001 | 1.65 | .01 | | | | | | |
| DM | .02 | <.05 | .17 | .09 | | | 0.96 | .12 | | |
| PV | 2.28 | <.001 | 1.56 | <.005 | | | | | | |
| GDP | 2.15 | <.05 | | | .49 | .38 | | | | |

Table 4. Errors produced by the patients in the picture naming task. *Latency* refers to correct responses given more than 3 seconds after the presentation of the stimulus. The category *Other* includes null responses, perseverations, circumlocutions, and neologisms.

(a) Nouns

| | | Error type | | | | | |
|---|---|---|---|---|---|---|---|
| | N correct | Formal paraphasia | Semantic paraphasia | Verbal paraphasia | Latency | Other | Total |
| LZ | 21 | 0 | 5 | 0 | 4 | 0 | 30 |
| FC | 26 | 0 | 1 | 0 | 1 | 2 | 30 |
| UB | 26 | 0 | 1 | 0 | 1 | 2 | 30 |
| MC | 22 | 0 | 1 | 0 | 0 | 7 | 30 |
| DM | 4 | 0 | 2 | 0 | 3 | 21 | 30 |
| PV | 5 | 0 | 1 | 0 | 0 | 24 | 30 |
| GDP | 4 | 0 | 7 | 0 | 2 | 17 | 30 |

(b) Verbs

| | | Error type | | | | | |
|---|---|---|---|---|---|---|---|
| | N correct | Formal paraphasia | Semantic paraphasia | Verbal paraphasia | Latency | Other | Total |
| LZ | 15 | 0 | 17 | 1 | 3 | 4 | 40 |
| FC | 12 | 0 | 12 | 9 | 2 | 5 | 40 |
| UB | 19 | 0 | 13 | 4 | 2 | 2 | 40 |
| MC | 4 | 0 | 13 | 14 | 3 | 6 | 40 |
| DM | 15 | 0 | 11 | 0 | 2 | 12 | 40 |
| PV | 23 | 0 | 5 | 0 | 3 | 9 | 40 |
| GDP | 16 | 0 | 9 | 0 | 1 | 14 | 40 |

Table 5. Patients' production of content verbs and nouns in spontaneous speech.

*Legend*: N, raw number of tokens, types or stems produced in a given category; *%*, percentage of tokens, types or stems produced in a given category on the total number of tokens/types/stems; *t*, modified *t* value (Sokhal & Rohlf, 1995); *p*, one-tailed *p* value; *, significant values at .05 level; ^, quasi-significant values at .05 level.

| | | | | Content verbs | | | | Nouns | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PNT | Pt | AT | Count | N | % | *t* | *p* | N | % | *t* | *p* |
| N>V | LZ | NFlu | Token (N=242) | 32 | 13 | -0.73 | .23 | 74 | 31 | 3.99* | .00 |
| | | | Type (N=97) | 17 | 18 | -1.27^ | .11 | 41 | 42 | 6.08* | .00 |
| | | | Stem (N=92) | 14 | 16 | -0.58 | .28 | 40 | 44 | 4.59* | .00 |
| | FC | NFlu | Token (N=147) | 21 | 14 | -0.15 | .44 | 51 | 35 | 5.33* | .00 |
| | | | Type (N=74) | 13 | 18 | -1.25^ | .11 | 37 | 50 | 8.63* | .00 |
| | | | Stem(N=71) | 12 | 17 | -0.12 | .45 | 37 | 52 | 6.64* | .00 |
| | UB | Flu(W) | Token (N=283) | 56 | 20 | 2.83 | .99 | 44 | 16 | -0.88 | .81 |
| | | | Type (N=128) | 39 | 30 | 3.93 | .99 | 32 | 25 | 0.37 | .36 |
| | | | Stem (N=106) | 26 | 25 | 2.73 | .99 | 31 | 30 | 0.73 | .23 |
| | MC | Flu(W) | Token (N=309) | 63 | 20 | 3.16 | .99 | 50 | 16 | -0.67 | .75 |
| | | | Type (N=143) | 40 | 28 | 2.93 | .99 | 30 | 21 | -0.96 | .83 |
| | | | Stem (N=106) | 18 | 17 | -0.10 | .39 | 29 | 27 | 0.00 | .50 |
| V>N | DM | Flu(A) | Token (N=300) | 54 | 18 | 1.86* | .04 | 58 | 19 | 0.35 | .64 |
| | | | Type (N=131) | 33 | 25 | 1.81* | .04 | 33 | 25 | 0.44 | .67 |
| | | | Stem (N=100) | 17 | 17 | -0.09 | .54 | 31 | 31 | 0.98 | .83 |
| | PV | Flu(A) | Token (N=312) | 59 | 19 | 2.36* | .01 | 53 | 17 | -0.41 | .34 |
| | | | Type (N=140) | 37 | 26 | 2.31* | .01 | 34 | 24 | 0.14 | .55 |
| | | | Stem (N=113) | 23 | 20 | 1.06^ | .15 | 30 | 27 | -0.22 | .41 |
| | GDP | Flu(W) | Token (N=309) | 66 | 21 | 3.68* | .00 | 36 | 12 | -2.14* | .02 |
| | | | Type (N=143) | 43 | 30 | 3.77* | .00 | 23 | 16 | -2.57* | .01 |
| | | | Stem (N=104) | 24 | 23 | 1.99* | .03 | 21 | 20 | -1.92* | .03 |

Table 6. Patients' production of function (closed-class) verbs in spontaneous speech. Stem *t* values were not calculated because of the low number of closed-class verb lexical entries.

*Legend*: N, raw number of tokens, types or stems produced in a given category; *%*, percentage of tokens, types or stems produced in a given category on the total number of tokens/types/stems; *t*, modified *t* value (Sokhal & Rohlf, 1995); *p*, two-tailed *p* value; *, significant values at .05 level; ^, quasi-significant values at .05 level.

| | | | | Function verbs | | | |
|---|---|---|---|---|---|---|---|
| PNT | Pt | AT | Count | N | % | *t* | *p* |
| N > V | LZ | NFlu | Token | 0 | 0 | -2,38* | .02 |
| | | | Type | 0 | 0 | -2,62* | .01 |
| | | | Stem | 0 | 0 | -- | |
| | FC | NFlu | Token | 0 | 0 | -2,38* | .02 |
| | | | Type | 0 | 0 | -2,62* | .01 |
| | | | Stem | 0 | 0 | -- | |
| | UB | Flu(W) | Token | 16 | 6 | .58 | .57 |
| | | | Type | 6 | 5 | .76 | .45 |
| | | | Stem | 3 | 3 | -- | |
| | MC | Flu(W) | Token | 7 | 2 | -1,19 | .24 |
| | | | Type | 5 | 3 | - .10 | .92 |
| | | | Stem | 3 | 3 | -- | |
| | DM | Flu(A) | Token | 15 | 5 | .24 | .82 |
| | | | Type | 3 | 2 | - .97 | .34 |
| | | | Stem | 1 | 1 | -- | |
| | PV | Flu(A) | Token | 12 | 4 | - .37 | .71 |
| | | | Type | 4 | 3 | - .56 | .58 |
| | | | Stem | 2 | 2 | -- | |
| | GDP | Flu(W) | Token | 21 | 7 | 1.17 | .25 |
| | | | Type | 8 | 6 | 1.41 | .17 |
| | | | Stem | 3 | 3 | -- | |

Table 7. Patients' overall production of closed-class and open-class words.

*Legend*: N, raw number of tokens, types or stems produced in a given category; *%*, percentage of tokens, types or stems produced in a given category on the total number of tokens/types/stems; *t*, modified *t* value (Sokhal & Rohlf, 1995); *p*, two-tailed *p* value; *, significant values at .05 level; ^, quasi-significant values at .05 level.

| | | | | Open class words | | Closed class words | | | |
|---|---|---|---|---|---|---|---|---|---|
| PNT | Pt | AT | Count | N | % | N | % | *t* | *p* |
| N>V | LZ | NFlu | Token | 131 | 54 | 111 | 46 | -4.49* | .00 |
| | | | Type | 72 | 74 | 25 | 26 | -5.33* | .00 |
| | | | Stem | 68 | 76 | 22 | 24 | -4.24* | .00 |
| | FC | NFlu | Token | 79 | 54 | 68 | 46 | -4.36* | .00 |
| | | | Type | 55 | 74 | 19 | 26 | -5.36* | .00 |
| | | | Stem | 54 | 76 | 17 | 24 | -4.36* | .00 |
| | UB | Flu(W) | Token | 104 | 37 | 179 | 63 | 0.95 | .35 |
| | | | Type | 73 | 57 | 55 | 43 | -0.39 | .70 |
| | | | Stem | 59 | 57 | 44 | 43 | -0.07 | .95 |
| | MC | Flu(W) | Token | 115 | 37 | 194 | 63 | 0.80 | .43 |
| | | | Type | 71 | 50 | 72 | 50 | 1.73^ | .09 |
| | | | Stem | 48 | 45 | 58 | 55 | 2.68* | .01 |
| V>N | DM | Flu(A) | Token | 119 | 40 | 181 | 60 | 0.04 | .97 |
| | | | Type | 73 | 56 | 58 | 44 | -0.02 | .99 |
| | | | Stem | 53 | 53 | 47 | 47 | 0.91 | .37 |
| | PV | Flu(A) | Token | 126 | 40 | 186 | 60 | -0.19 | .85 |
| | | | Type | 81 | 58 | 59 | 42 | -0.63 | .53 |
| | | | Stem | 63 | 56 | 50 | 44 | 0.28 | .78 |
| | GDP | Flu(W) | Token | 127 | 41 | 182 | 59 | -0.41 | .68 |
| | | | Type | 82 | 57 | 61 | 43 | -0.43 | .63 |
| | | | Stem | 58 | 56 | 46 | 44 | 0.28 | .78 |

# Figure Captions

Figure 1. Possible interpretation of noun-verb written-oral double dissociation, with particular reference to the semantic system (a), or to the lemma store (b). Dashed lines indicate the semantic-lexical (a) and lemma-lexeme (b) interfaces that may be impaired in patients showing oral-written double dissociations, similarly to KSR (Rapp and Caramazza, 2002).

Figure 2: Token, type and stem production shown by the patients in the grammatical class that was mostly impaired in a picture naming task: (a) verb production profiles of non-fluent verb-impaired patients; (b) verb production profiles of fluent verb-impaired patients; (c) noun production profiles of fluent noun-impaired patients.

Figure 3: Schematic representation of the cognitive damage underlying a verb- or noun-specific impairment that is likely to emerge in picture naming task, but not in patients' connected speech.

# FIGURES

Figure 1

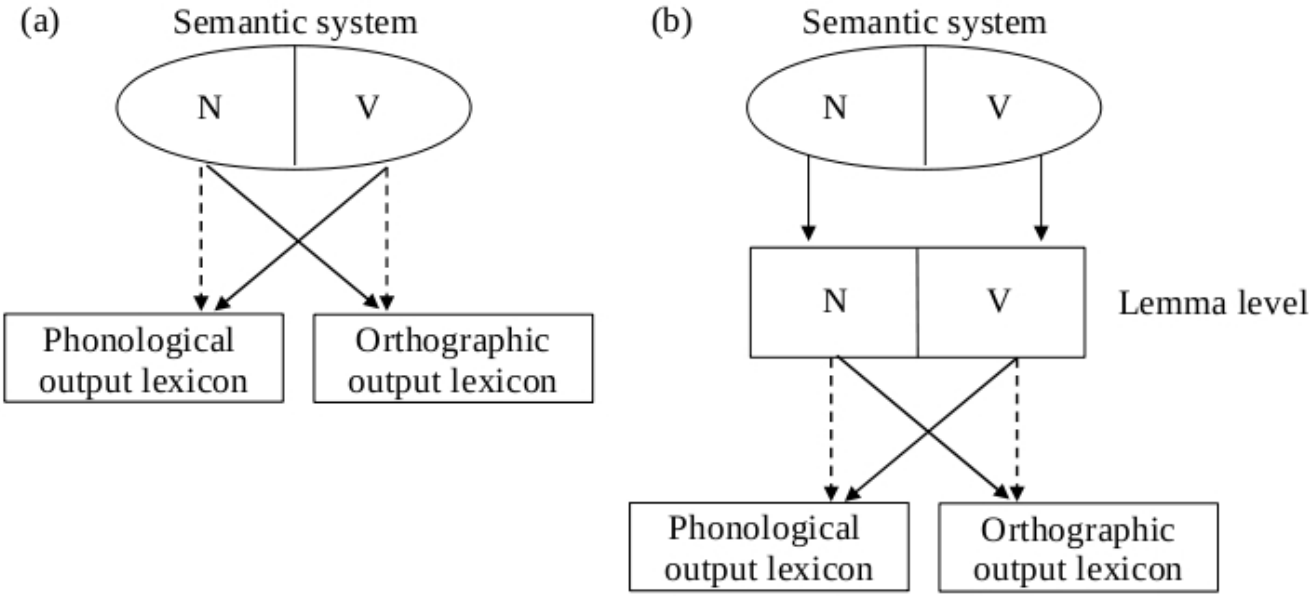


Figure 2

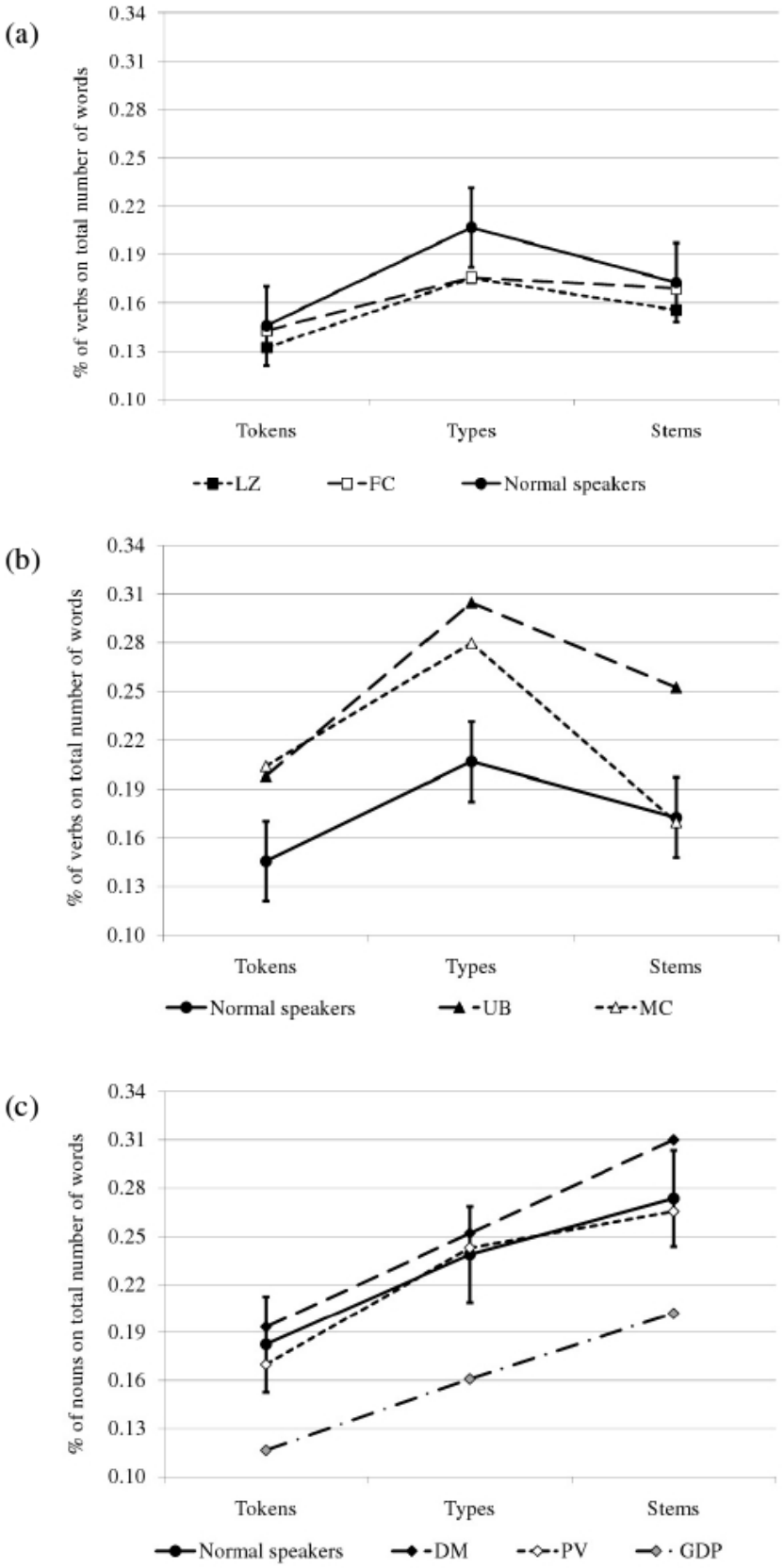
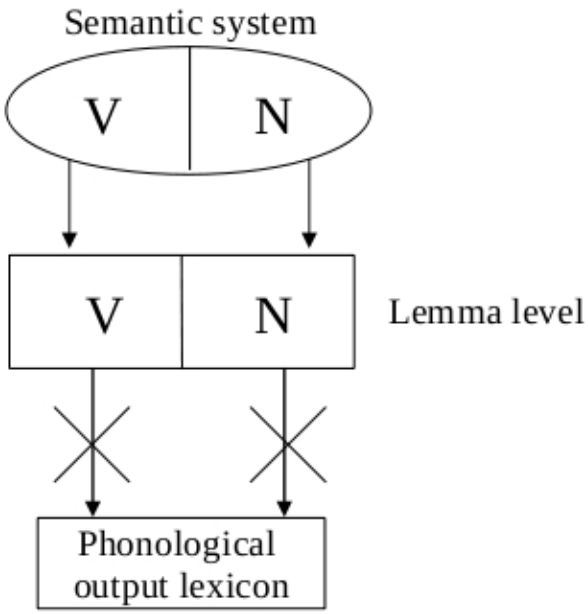

(a)
% of verbs on total number of words
0.34
0.31
0.28
0.25
0.22
0.19
0.16
0.13
0.10
Tokens
Types
Stems
LZ
FC
Normal speakers
(b)
% of verbs on total number of words
0.34
0.31
0.28
0.25
0.22
0.19
0.16
0.13
0.10
Tokens
Types
Stems
Normal speakers
UB
MC
(c)
% of nouns on total number of words
0.34
0.31
0.28
0.25
0.22
0.19
0.16
0.13
0.10
Tokens
Types
Stems
Normal speakers
DM
PV
GDP

Figure 3


Semantic system
V
N
V
N
Lemma level
Phonological
output lexicon

# APPENDIX A

Number of tokens, types and stems produced by each patient in the following five categories: (i) open-class, lexical verbs (OC verbs), (ii) nouns, (iii) other open-class items (adjectives and open-class adverbs, e.g., 'slowly'; OC others), (iv) closed-class, function verbs (copulae, auxiliaries and modals; CC verbs), and (v) other closed-class items (articles, prepositions, numerals, pronouns, possessives, adverbs not derived from adjectives, e.g., 'quasi', 'almost', and conjunctions; CC others). The sum of (i), (ii) and (iii) constitutes the total amount of open-class items produced by each patient in her spontaneous speech, while (iv) and (v) add up to form the total number of closed-class items.

*Legend*: *PNT*, noun-verb dissociation as revealed by the picture naming task.

| PNT | Pt | AT | Count | OC verbs | Nouns | OC others | CC verbs | CC others | Total |
|---|---|---|---|---|---|---|---|---|---|
| N>V | LZ | NFlu | Token | 32 | 74 | 25 | 0 | 111 | 242 |
| | | | Type | 17 | 41 | 14 | 0 | 25 | 97 |
| | | | Stem | 14 | 40 | 14 | 0 | 22 | 92 |
| | FC | NFlu | Token | 21 | 51 | 7 | 0 | 68 | 147 |
| | | | Type | 13 | 37 | 5 | 0 | 19 | 74 |
| | | | Stem | 12 | 37 | 5 | 0 | 17 | 71 |
| | UB | Flu(W) | Token | 56 | 44 | 4 | 16 | 163 | 283 |
| | | | Type | 39 | 32 | 2 | 6 | 49 | 128 |
| | | | Stem | 26 | 31 | 2 | 3 | 41 | 106 |
| | MC | Flu(W) | Token | 63 | 50 | 2 | 7 | 187 | 309 |
| | | | Type | 40 | 30 | 1 | 5 | 67 | 143 |
| | | | Stem | 18 | 29 | 1 | 3 | 55 | 106 |
| V>N | DM | Flu(A) | Token | 54 | 58 | 7 | 15 | 166 | 300 |
| | | | Type | 33 | 33 | 7 | 3 | 55 | 131 |
| | | | Stem | 17 | 31 | 5 | 1 | 46 | 100 |
| | PV | Flu(A) | Token | 59 | 53 | 14 | 12 | 174 | 312 |
| | | | Type | 37 | 34 | 10 | 4 | 55 | 140 |
| | | | Stem | 23 | 30 | 10 | 2 | 48 | 113 |
| | GDP | Flu(W) | Token | 66 | 36 | 25 | 21 | 161 | 309 |
| | | | Type | 43 | 23 | 16 | 8 | 53 | 143 |
| | | | Stem | 24 | 21 | 13 | 3 | 43 | 104 |