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Grammatical class effects in brain-damaged patients: Functional locus of noun and verb deficit

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Abstract

Two patients are described with grammatical class dissociation: CG, a semantic-dementia patient who presented a disproportionate impairment of nouns compared to verbs; SA, a patient with a left parietal lesion who presented impaired sentence production and a disproportionate deficit for verbs compared to nouns. The results are discussed within the current models on semantic memory and lexical access.

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1. Introduction

Categories of words may be differentially affected in brain lesions (Robinson, Grossman, Tammy White-Devin, & D'Esposito, 1996). Not only semantic categories (first of all living and non-living items) but also grammatical classes (that is, nouns and verbs) may be selectively damaged or spared in patients with lesions involving different cerebral areas. Even if we admit that for intrinsic reasons verbs may be more vulnerable than nouns (Gentner, 1991) and thus more sensitive to the effects of cerebral lesions (Bird, Howard, & Franklin, 2000; Breedin, Saffran, & Schwartz, 1998; Kohn, Lorch, & Pearson, 1989; Williams & Canter, 1987), and that different nuisance factors may potentially create the basis for artifactual dissociation (Kemmerer & Tranel, 2000), the demonstration of *double dissociation* between nouns and verbs processing with the same testing materials (Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; Miceli, Silveri, Villa, & Caramazza, 1984; Zingeser & Berndt, 1988; Silveri & Di Betta, 1997) definitely exclude the “artifactual” hypothesis. Other evidence underpins the non-artefactual nature of the grammatical class effects.

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First, neuropathological data suggest that the cerebral areas correlated to noun and verb processing are segregated and that different neurofunctional circuits contribute to elaborate different classes of words (Damasio & Tranel, 1993; Daniele et al., 1994; Grossman, 1998). Convergent evidence is provided by functional (PET) studies (Cappa et al., 1998; Warburton et al., 1996).

Second, the clinical context in which noun and respectively verb deficit is observed is quite different: Patients with reduced ability to process verbs are generally agrammatic while patients with reduced ability to process nouns are anomic without any problem with sentence construction (Daniele et al., 1994; Miceli, Silveri, Nocentini, & Caramazza, 1988; Myerson & Goodglass, 1972; Silveri & Di Betta, 1997; Zingeser & Berndt, 1988, 1990). In spite of the criticism expressed towards symptom association as poor index of functional organisation (but see Caramazza, 1986), the described associations are too frequent to be ignored. They may simply express a neural contiguity between different functions but in the general economy of the brain organisation also this neural proximity could not be casual.

A few patients however, suggest that agrammatism and verb deficit are not invariably associated (Berndt, Haendiges, Mitchum, & Sandson, 1996a,b; Caramazza & Hillis, 1991). However, in one of these (Berndt et al., 1996a,b) a deficit of sentence production was demonstrated; in the other two, no satisfactory description of sentence integrity was available and verb deficit itself was very mild (see Berndt, Haendiges, & Wosniak, 1997 for a discussion). In conclusion, none of these “exceptions” does represent definitive counter evidence of the association between verb deficit and agrammatism.

A further question is of note. A deficit in sentence construction is not necessarily expression of non-fluent aphasia but it may also characterise the speech production of fluent aphasics. Some patients with selective verb deficit have indeed fluent aphasia and paragrammatic speech (Berndt et al., 1997; Silveri & Di Betta, 1997).

Subjects with word class deficit in production tasks may or may not present a comparable deficit in comprehension. In fact, in some cases reduced verb production is described in association to impaired verb comprehension (Daniele et al., 1994; McCarthy & Warrington, 1985) but other patients had been described in which verb comprehension was preserved (Caramazza & Hillis, 1991; Silveri & Di Betta, 1997). At the same time, impaired noun production may be associated to impaired noun comprehension in some cases (Daniele et al., 1994; Silveri & Di Betta, 1997), but not in others (Silveri & Di Betta, 1997). The issue of single word comprehension needs attention since a low comprehension is generally interpreted as indicative of semantic impairment. In other words, a preserved comprehension would indicate that grammatical class dissociation arises downstream the semantic level, while poor comprehension would implicate a degradation at the level of the semantic representation, allowing an interpretation of grammatical class dissociation in terms of category specific deficit for “objects” and “actions.” However, a comprehension deficit selective for one grammatical class and specific for one modality of input (auditory or visual) has been interpreted in support of the view that not only the output lexicon(s) but also the input lexicon(s) is organised according to grammatical class (Miceli et al., 1988).

In general, the corpus of evidence on noun and verb impairment basically generated two orders of hypotheses: The first assumes that nouns and verbs are modularly distinct within the lexical-semantic system and may be differentially affected by brain lesions. The second interprets the verb deficit as an expression of a more general syntactic disorder. The lexical-semantic hypothesis assumes different versions. Verb and/or noun impairment may express a selective loss of word class information at the level of the central semantic system (Daniele et al., 1994; McCarthy

& Warrington, 1985) that is, a category specific semantic deficit, or at least a sensitivity to a semantic variable as proposed by Breedin et al. (1998). Alternatively, a word class impairment may be the consequence of a lexical deficit, assuming, in the strongest view, that word classes are redundantly represented within independent (phonological or orthographic) output (Caramazza & Hillis, 1991) or input (auditory or visual) lexicons (Miceli et al., 1988). The possibility remains open that the grammatical class effect could be lexical in nature but independent of the lexical form, so that the same pattern of performance could be observed in all the input and output lexical modalities. This evenience is however virtually indistinguishable from a semantic deficit affecting all the input and output lexical modalities (see Gainotti, Silveri, Daniele, & Giustolisi, 1995 for a discussion).

In recent papers, some attempts have been made to interpret the grammatical class deficit for the class verbs observed in aphasia, within the current models of sentence production (Garret, 1988; Levelt, 1992) focusing on the components of the models that specifically deal with single word selection, that is, the lexical access for verbs. These models assume (similarly to models formulated for single word production) two levels of lexical access: A “lemma” level, an abstract lexical representation that specifies semantic and syntactic information, and a “lexeme” level that specifies phonological or orthographic information. Evidence in favour of deficits at both levels of lexical access has been provided.

These models consider the agrammatic features associated to single verb production impairment a secondary deficit. In details, the defective lexical access to verb would prevent the formulation of a correct sentence. However, so far, no definitive counter evidence has been provided to refuse the opposite, original hypothesis (Saffran, Schwartz, & Marin, 1980; Saffran, 1982), of a primary syntactic deficit that precludes the correct verb selection.

Here we report two patients. The first, CG, was affected by semantic dementia (Hodges, Patterson, Oxbury, & Funnell, 1992; Snowden, Goulding, & Neary, 1989). He presented deep anomia (see also Silveri et al., 1997 for a previous description) as a consequence of a progressive and radical impoverishment of the lexical-semantic knowledge but a good preservation of other aspects of language, such as syntax and phonology. Within nouns, inanimate items were more impaired than animate items (see previous report, Silveri et al., 1997).

The second, SA, had a small ischemic lesion in the left posterior parietal region. She presented phonological impairment, very low verbal span, agrammatic speech, and poor syntactic comprehension, but no evidence of semantic deficit. The first patient presented a selective loss of noun compared to verb; the second an opposite pattern.

Aim of the study was to further explore the nature of the grammatical class effect; in details, which is the functional locus of noun and of verb impairment in patients with cerebral lesions and the relationship between verb impairment and impaired sentence construction.

2. Cases report

2.1. Patient CG

CG was a 66 year-old right-handed chemist. He was tested the first time in 1993. The neuroradiological examination (MRI) had revealed a left polar atrophy (Fig. 1a), while the functional study (PET) had confirmed the presence of a significant hypometabolism in the left temporal, hippocampal and parahippocampal girus, and

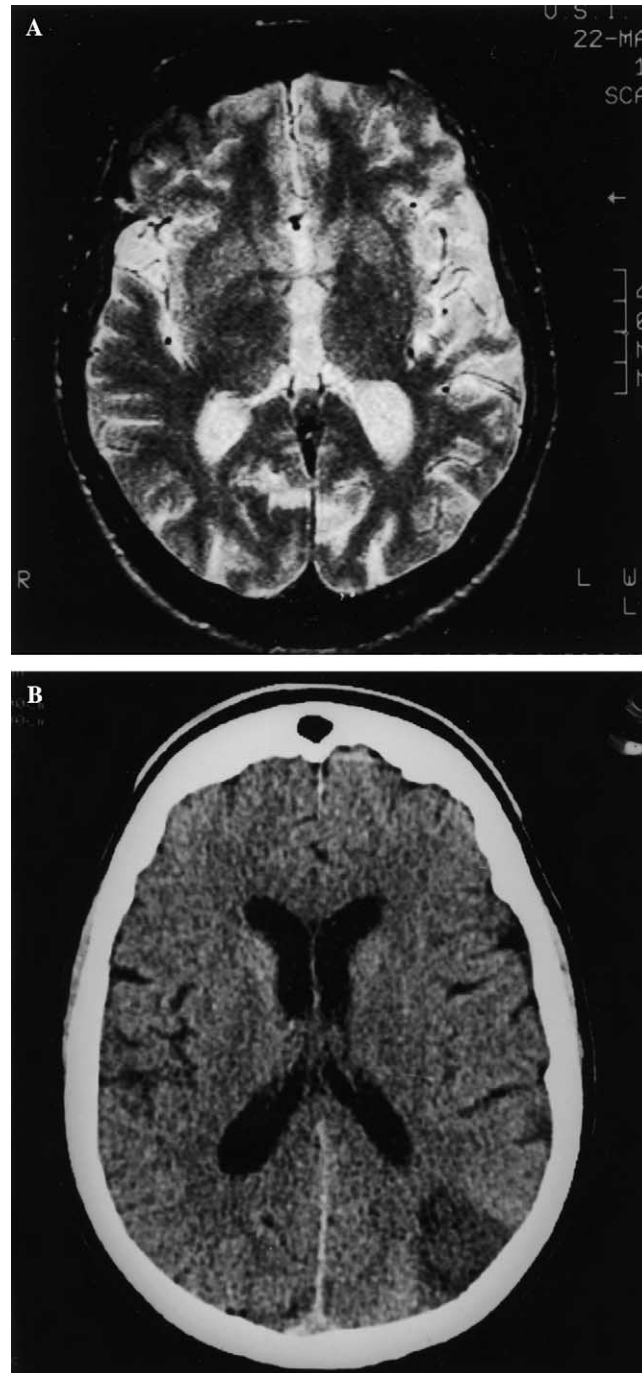


Fig. 1. (A) Patient CG: MRI showing the left temporal atrophy; (B) patient SA: TC scan showing the ischemic lesion in the left posterior parietal lobe.

in the the inferior parietal lobule (see Silveri et al., 1997, for a previous report). At that time, the patient presented a pure anomia with verb preservation. Non-linguistic cognitive domains were intact. The dissociation was interpreted within the lexical level even if the possibility was also acknowledged that comprehension tasks

could not be so sensitive to discover a mild semantic deficit. This interpretation was confirmed in further examinations performed along the following years, when the semantic deficit became progressively more evident. The patient was in fact checked up from 1994 to 2000. The dissociation between nouns and verbs was mild at the first examinations (see Silveri et al., 1997) but in the following years it became striking.

2.2. Neuropsychological examination

The patient was extensively examined on 1994, 1995, 1997, and 1999. His spontaneous speech was fluent, normoprosodic, and grammatical until later stages when word finding problems became evident. However, word finding in spontaneous speech never was so severe to suspect the severity of anomia in confrontation naming. On 1997 he still performed within the normal range in immediate and delayed free recall of words (obtained scores: 41 vs 6; adjusted scores: 40.5 vs 6.1; cut-off: 28.53 vs 4.69) and Raven Coloured Matrices (obtained score: 33; adjusted score: 30.7; cut-off: 18.96). Phonological word fluency was normal as well: obtained score: 29; adjusted score: 21.8; cut-off: 17.35. IQ was still normal on 1998 (IQ = 111). On 1999 patient's performances were moderately reduced but still close to normality (immediate and delayed free recall of words: obtained score: 19 vs 2; adjusted score: 20.3 vs 2.8; cut-off: 28.53 vs 4.69; Raven: obtained score: 28; adjusted score: 26.4; cut-off: 18.96). Attention tasks, visuoconstructional tasks and praxis were completely normal until 1999. Visual perceptual abilities were explored by means of the visual object and space perception battery (VOSP) by James and Warrington (1991). On 1998 the patient obtained fully normal scores either on object decision or space perception subsets. IQ score was 112. On 1999 he showed a slight impoverishment on some object decision subsets (silhouettes: 15; cut-off 16; object decision: 14; cut-off 14; progressive silhouettes: 9; cut-off: 15), but space perception subsets were still normal. Verbal and visual span were within normal range (6 vs 6 in 1999). On that date, the patient's ability to name famous faces was virtually abolished (1/40 correct). When he was requested to tell some information on the identity of the face he could not recognise he was impaired as well. Late on 2000 his naming ability was virtually abolished, but he was still able to occasionally produce verbs in confrontation naming. Episodic memory was impaired when tested by means of free recall of words but CG was still normal in recalling Rey's complex figure. Visuo-spatial and attentional tasks (simple and double cancellation tasks) were still normal as well as constructional, oral and limb apraxia. Verbal span was 6 forwards and 5 backwards. At that time the patient was still oriented in time and in place.

2.3. Language

Until 1999, phoneme discrimination was normal (30/30) as well as word repetition (45/45), word reading (92/92), and writing (27/30). Occasional spelling errors were produced on non-words (repetition: 30/35; writing: 41/45); non-word reading was normal (44/45). Auditory comprehension of sentences and visual comprehension of sentences were normal (60/60 and 44/45, respectively). A progressive decay of the naming performance was documented. Within nouns, living items were persistently named better than non-living items, but in 1997 both categories were very close to floor. However, the patient was still able to name a considerable amount of verbs. Word comprehension was round 70% correct on 1999, also in this case living items demonstrated a moderate advantage compared to non-living item (80% correct on living items; 67.5% correct on non-living items).

2.4. Patient SA

SA was a 63-year-old woman with 8 years of formal education. Until the age of 60 she had been employed as tailor. On May 1997 she developed the sudden onset of right side paresthesia and disorder of speech. At the admission, a moderate sensory-motor deficit was detected in the superior and inferior right limb associated to right homonymous hemianopia. Speech was markedly reduced and paraphasic. The motor deficit improved rapidly within few hours. Systematic distal right extinction to double sensory and visual stimuli persisted. The CT-scan revealed the presence of a small ischemic area in the distal territory of the left middle cerebral artery (see Fig. 1b).

2.5. Language and general neuropsychological examination

Spontaneous speech was ipofluent, with normal articulation, and prosody, with frequent phonemic paraphasias. Sentences were shorter than normal, moderately agrammatic because of verbs in infinitive form, omission of freestanding grammatical morphemes and agreement violations. Discrimination of couples of non-sense syllables was only marginally impaired (27/30 correct) (cut-off: 29/30). Lexical decision task was reduced in auditory modality (70/80 correct) and normal in visual modality (100/100 correct). Word and non-word repetition, writing to dictation and reading were impaired because of phonological errors (words: 21/45, 15/46, and 60/92 correct, respectively; non-words: 23/36, 21/24, and 35/44 correct). Sentence repetition was markedly impaired (only two out of 20 sentence correctly repeated) as well.

Confrontation naming was close to normality for objects but very low when actions were used as stimuli. Single word comprehension was normal (100%). Free recall of words and fluency could not be performed because of the patient's refusal, presumably because of difficulty in word production. Raven Coloured Matrices were reduced (obtained score: 15; adjusted score: 16.4; cut-off: 18.96). Simple and double cancellation tasks were normal in spite of the visual field defect and right extinction at the double visual stimulation. Oral, limb, and constructional praxis were normal. The patient had very low verbal span (between 1 and 2) but obtained normal score at Corsi's test (6 forward).

3. Longitudinal examination

CG was followed-up for 7 years approximately. We could thus documented a progressive decay of the performance in naming and in other lexical-semantic tasks. SA was tested shortly after the stroke. Her performance evolved rapidly and 3 months later, she was no longer aphasic. Only a moderate impairment in transcoding tasks, especially in writing on dictation, was still present.

4. Patients' performances on noun and verb

4.1. Material

Both patients received oral and written naming tasks for objects and actions and noun and verb comprehension tasks (word picture matching) from the batteria for the analysis of the aphasic deficit (BADA) (Miceli, Laudanna, Burani, & Capasso,

1994). In these tasks nouns and verbs are matched for word frequency and length. We will refer to these tests as BADA tests. The comprehension tasks are based on word picture matching technique (two pictures: The target and a phonological (e.g., *treccia/freccia*) [plait/arrow] or a semantic (e.g., *cat–dog*) foil).

The patients also received the noun and verb battery used in a previous study (Miceli et al., 1988) including object and action naming and object and action comprehension tasks (word picture matching). In this battery the same stimuli are used for naming and comprehension (word picture matching task). Nouns and verbs are controlled for word frequency and length. In the comprehension tasks the target is contrasted with a semantic and an unrelated alternative. We will refer to these tests as noun/verb tests. Patient CG also received the items of a task devised by Collina, Marangolo, and Tabossi (2001). This task was given as naming test, since when given in the original procedure the scores were close to floor. In this task nouns and verbs are matched for lexical-semantic variables such as word frequency, imageability, and concreteness. In addition, number of arguments is kept under control. Patient SA did not perform this task since it was no available at the time of the examination.

5. Results

5.1. Patient CG

5.1.1. Oral and written naming

As Fig. 2 shows, CG presented a progressive decay of the ability to name nouns both in oral and in written modalities, both in BADA and in noun/verb tests. While the severity of anomia for nouns progressively increased through sessions, verb production was only slightly impaired and did not show any clear negative evolution until 1997. In 1998 also verb's decline became evident but the deficit remained significantly milder compared to noun's.

5.2. Auditory and visual comprehension

Verb comprehension (auditory and written) was normal until 1997. In 1998 some comprehension errors were produced on nouns but not on verbs. In 1999 errors were produced in comprehension also on verbs but to a significant lesser extent than on nouns. The same patterns could be documented in all the comprehension tasks and both in auditory and visual modalities (Fig. 3).

5.3. Comprehension of word meaning

Comprehension was studied on 1999, when it was severe enough to allow a statistical analysis. The stimuli of oral and written naming of BADA were used. Single nouns or verbs were pronounced to the patient that was requested to give as much as possible information on the item. Nouns and verbs were given in pseudo random order (100 nouns and 39 verbs). Two independent judges were requested to assign a score ranging from 0 to 3 to each response provided by the patient. The scores were assigned according to the following criteria: 0: no correct information; 3: all the information provided was appropriate; 1: at least one correct semantic feature had been provided; 2: more than 1 semantic feature had been provided but the information was not sufficient for a correct definition of the item. Noun's knowledge

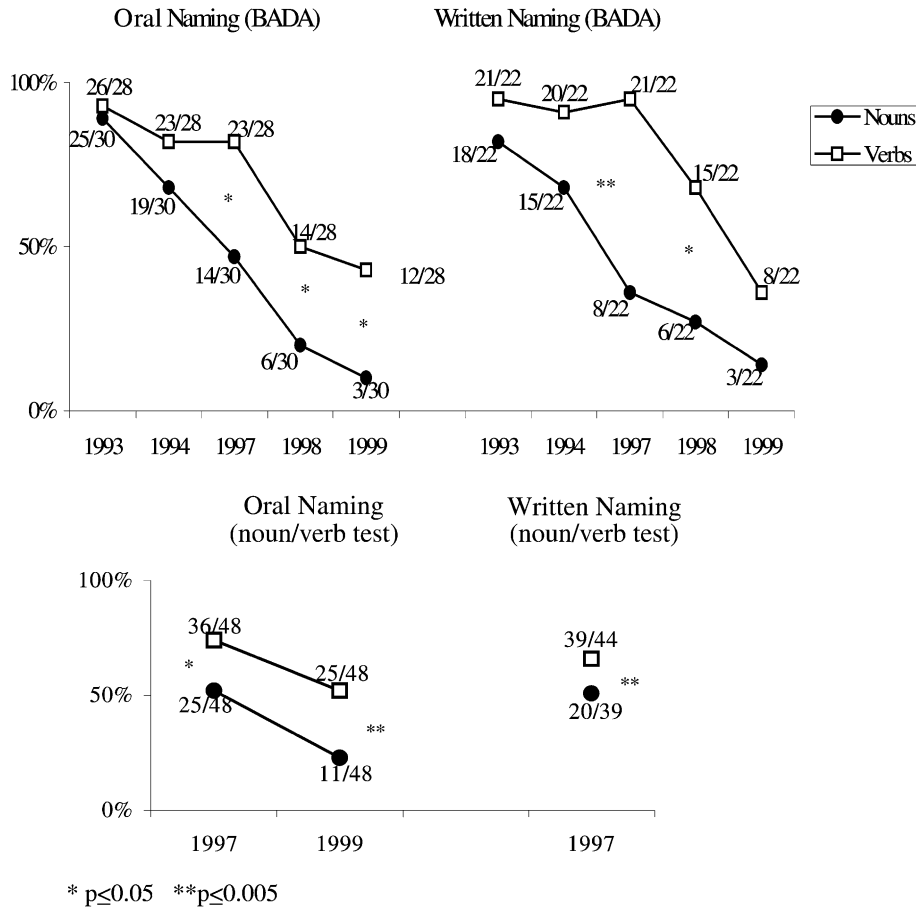


Fig. 2. CG's performance (through sessions) in oral and written naming of nouns and verbs (the asterisks indicate the statistical significance of the X^2 between the performance obtained on nouns and on verbs in the same session).

reached a mean value of 1.92 and verb's knowledge a mean value of 2.40 ($t = 2.365$; $p < .021$).

5.4. Qualitative analysis of naming errors

In the first stages of the disease the patient produced only anomias and demonstrated to be able to give a reasonable good definition of the item he could not name. However, he was not sensitive to phonological cueing. In later stages the patient also produced a considerable amount of semantic paraphasias in addition to anomias. Phonological errors never were produced.

5.5. Regression analysis

To explore the frequency effect independently of the category effect, a regression analysis was applied to the scores obtained in oral and written naming of BADA test performed on 1993, 1994, 1997, 1998, and 1999. More frequent items were always named with higher accuracy. Word frequency effect reached a significant level in oral naming in 1997 ($p = .031$) and in 1999 ($p = .034$), in written naming in 1998 ($p = .029$).

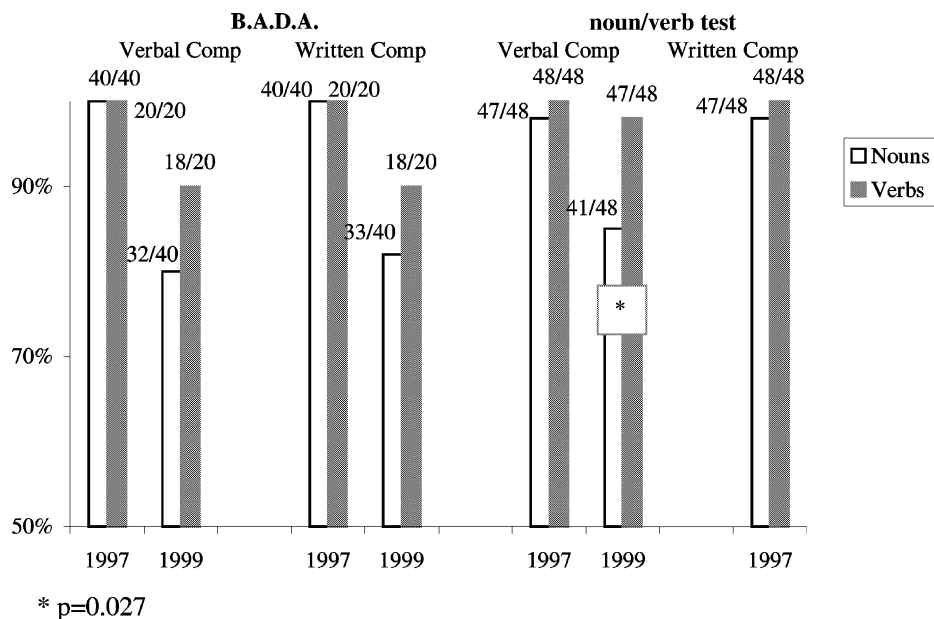


Fig. 3. CG's performance (through sessions) in auditory and written comprehension of nouns and verbs (the asterisk indicates the statistical significance of the X^2 between the performance obtained on nouns and on verbs in the same session).

5.6. Effect of semantic complexity on naming ability (argument structure)

This test was administered in order to investigate a specific aspect of the semantic of nouns and verbs, the complexity of the thematic roles, that is, the semantic relations expressed by the arguments of noun and verb. Nouns and verbs are not equivalent regarding the argument structure, being this less complex in nouns than in verbs. Even if it is known that this variable is less crucial for noun semantic definition compared to verb's, and thus it is quite improbable that CG's pattern of impairment (with prevalent deficit for nouns) could be related to it, nevertheless no direct evidence is available regarding the influence of argument structures of nouns and verbs in anomic patients. In addition, the test also allowed exploring lexical-semantic variables not specifically considered in the naming tests above described, the effect of concreteness and imageability. Difference in concreteness and imageability has been indicated as possible fonts of grammatical class dissociation. As we can see in Table 1, when items were matched for lexical variables and argument structure, the verbs were confirmed to be easier to name than the nouns. In addition, the number of arguments did not seem to influence the naming performance within the grammatical class. The verbs correctly named were more concrete and imageable than verbs not-named, although not significantly (mean imageability: named = 5.69 (.71); not-named = 5.3 (1.16); mean concreteness: named = 5.8 (.79); not-named = 5.6 (.08)). No analysis was allowed on nouns due to floor effect.

Table 1
Naming performance (correct responses) on nouns and verbs matched for word frequency, concreteness, imageability, and number of arguments (Collina et al., 2001)

	0 argument	1 argument	2 arguments
Noun	0/24	0/24	1/24
Verb	—	10/26	8/34

5.7. *Comment*

CG impairment was fully consistent with a semantic dementia. He was affected by a progressive lexical-semantic decay in absence of other major linguistic or cognitive deficits. Living categories were less impaired than non-living categories even if the lexical-semantic impairment involved all the semantic knowledge as the disease evolved. CG's deficit was classified as "pure lexical" in the earlier stages (Silveri et al., 1997) since comprehension seemed fully preserved. However a progressive impoverishment of the semantic knowledge, also in this case more severe for non-living beings, was documented later. Thus, the evolution casts doubts on the interpretation of CG's impairment in term of pure lexical deficit and would confirm that a lexical deficit may be expression of slight semantic impairment. Not only common names but also proper names were deeply impaired. Verb's knowledge seemed particularly resistant to the breakdown of the semantic memory as shown in comprehension tasks and in tasks in which the patient had to provide direct evidence about the knowledge of the item.

The grammatical class effect was cross modal in production (oral and written naming) and, when the comprehension tasks deteriorated, in input modalities. Direct evidence of a degradation of noun's meaning compared to verb's was provided by the significantly lower score obtained in definition's tasks. Although CG's general performance was sensitive to word frequency, concreteness, and imageability, none of these variables proved to be responsible of grammatical class effect, since the advantage of verb persisted when the items were balanced for these variables. No evidence was as well reached that the complexity of the argument structure could generate the dissociation. In addition, the complexity of the argument structure did not influence the performance within the same grammatical class (at least on verbs where the performance was not at floor), since less complex verbs were not named more accurately than more complex verbs.

The phonological and the syntactic level proved to be preserved until very late stages of the disease. In conclusion, the lexical-semantic deficit was very severe but remained relatively isolated. In this general context, the relative preservation of the verb suggests two hypotheses: that verb is not exclusively processed at the semantic level but plausibly relies on other competencies that are resistant to the degradation produced by the brain disease; alternatively, that verb's semantic is modularly distinct from noun's semantic and may be spared by the cerebral degeneration. In this latter case however, we should conclude that semantic dementia does not destroy all the semantic knowledge.

Apparently, in this patient the complexity of the argument structure did not affect naming general ability at variance with other lexical variables. If this last result could be confirmed we could speculate that the thematic role expresses a lexical-semantic dimension that does not affect lexical-semantic tasks. In this case we could conclude that semantic dementia involves denotative aspects of semantics but not semantic components such as the argument structure that is probably at the interface with syntactic aspects of language.

5.8. *Patient SA*

5.8.1. *Noun and verb naming and comprehension*

In this analysis the response produced was considered correct when it was lexically recognisable, in spite of phonological errors. Fig. 4 shows that in BADA test SA was dramatically impaired in action naming while object naming was only moderately reduced. The same tendency could be confirmed across modalities. In noun/verb test the same results were obtained. While object naming was round normality, actions were severely impaired, also in this case without difference between the two modalities

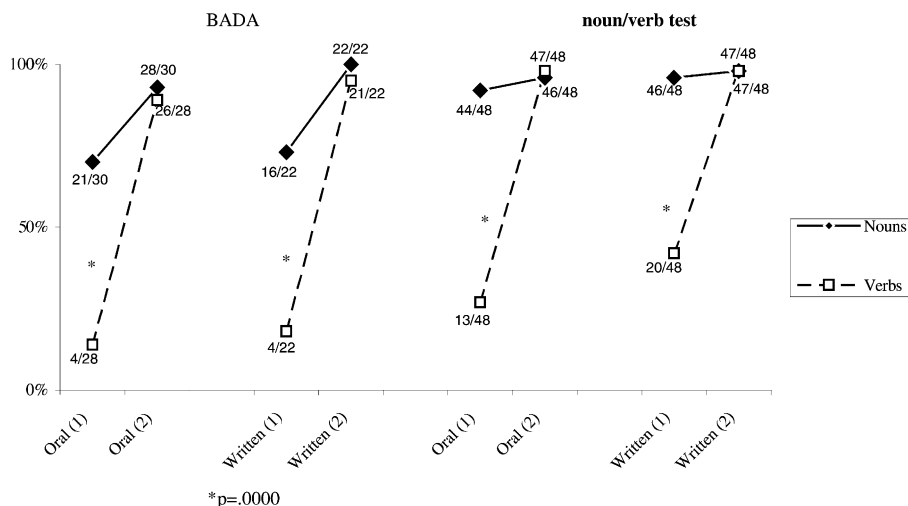


Fig. 4. SA's performance in oral and written naming (the asterisks indicate the statistical significance of the X^2 between the performance obtained on nouns and verbs in the same session). (1) = first examination; (2) = second examination.

(oral and written). Three errors out of 20 stimuli were produced in visual (written) verb comprehension; two out of three, were on phonological contrast, one was a non-response (the patient claimed the picture was not clear). Auditory comprehension was 20/20 correct. In noun/verb test SA produced two errors on nouns and three errors on verbs in auditory modality and one error on nouns and two errors on verbs in visual modality. Since these comprehension tasks are based only on semantic (but not phonological) contrasts, we could not discriminate if patient's difficulty was due to impaired phonological (or graphemic) decoding of the stimulus word. In any case, one out of three matched controls which received the tasks produced three errors on nouns and three errors on verbs both in auditory and in visual modalities. When SA was asked to mime actions, she was correct 18 out of 18 stimuli (verbs pronounced aloud by the examiner).

5.9. Transcoding nouns and verbs

No differences could be found between nouns and verbs in writing to dictation, reading, and repetition. SA was able to correctly read 12/20 verbs and 12/20 nouns matched for frequency and length. Similarly she correctly wrote on dictation and repeated seven out of 10 nouns and seven out of 10 verbs and 7/15 nouns, and 5/15 verbs, respectively. SA was also requested to read, write and repeat the stimuli of the naming tasks. No difference emerged between nouns and verbs (reading vs writing vs repetition: 26/30 vs 18/30 vs 29/30 correct on nouns; 23/28 vs 17/28 vs 28/28 correct on verbs).

5.10. Qualitative analysis of naming errors

Table 2 reports the total errors produced in naming nouns and verbs of BADA test and of noun/verb test. As shown in the table, SA made a considerable amount of phonological errors both in oral and in written modality. It is worth noting that proportionally, more phonological errors on nouns than on verbs were produced, suggesting that the phonological errors could be an expression of a less severe production deficit. The pattern of errors on verb naming confirmed to some extent this suggestion: The prevalent error in verb naming was the production of nouns in

Table 2
Qualitative analysis of naming errors produced by SA on nouns and verbs of BADA and noun/verb tests

	Oral (objects)	Written (objects)	Total (objects)	Oral (actions)	Written (actions)	Total (actions)
Items that elicited wrong responses	12/78 15%	7/70 10%	19/148 12.8%	59/76 78%	46/70 66%	105/146 71.9%
<i>Pool of errors</i>	23	19	42	53	47	100
%Phonological	39	57.8	47.6	9.4	25.5	17
%Semantic	8.6	5.3	7.1	7.5	0	4
%Anomia	30.4	36.8	33.3	23	21.3	22
%Verb in the place of nouns	4.3	0	2.3	0	0	0
%Noun in the place of verbs ^a	0	0	0	41.5	51	46
%Generic and visual	17.4	0	9.5	18.8	12	11

^a In this type of errors we included nominalisations, description of objects of the figure and expressions such as “*fa*” [he does] + name (nominalisations).

the place of verbs, as if the patient were virtually unable to produce verb. The other types of errors were equally distributed on nouns and verbs.

5.11. Regression analysis

A regression analysis was applied on naming performance of oral naming of BADA test. Frequency, length, and category were taken as independent factors. Only the category effect reached the significance (oral naming: $p=0.017$). However, when the lexically recognisable response with phonological errors were not included within the correct responses, also the factor length reached the statistical significance ($p = .029$). In neither analysis did the frequency effect reach the significance.

5.12. Short-term memory

SA showed a severe reduction of the digit-span. Auditory-verbal span was 1.8 while in visual-verbal modality the span increased to 2.8, suggesting reduced efficiency of the input phonological short term store as in the majority of short-term memory patients (Shallice & Vallar, 1990). However, an output component was suggested by the better performance in the pointing modality (visual-pointing = 2.6; auditory-pointing = 2.4).

5.13. Spontaneous speech

Sentence construction was impaired. SA produced 23/25 expected nouns, 41/43 expected verbs, and 46/51 expected function words; however out of 23 nouns produced, 5 were phonological errors, and one was morphological; out of 41 verbs produced 12 had morphological errors (six were infinitive forms) and one was semantic.

5.14. Sentence comprehension

The patient was requested to perform two tests of sentence comprehension based on sentence-picture matching technique: Two pictures-one sentence from the BADA (Miceli et al., 1994). The sentence was given either in spoken (60 stimuli) or in visual (written) modality (45 stimuli). Both tasks include semantically reversible sentences (the child kisses the mother), morphological contrasts (singular vs plural on the subject or on the object), semantic contrasts (on the subject, on the object, on the predicate).

Half stimuli were active sentences; half stimuli were in passive form. SA produced 10/20 errors on reversible sentences, 7/20 errors on morphological contrasts and 6/20 errors on semantic contrasts when the stimuli were given in spoken form. In visual form, she produced 3/15 errors on reversible sentences and no errors on 15 morphological and 15 semantic contrasts. Passive forms were as accurate as active forms. The spoken form of the task was performed again 3 months later; the patient produced only 10 errors: nine on reversible sentences and one on morphological contrasts.

5.15. *Grammaticality judgements*

On auditory grammaticality Judgements given in spoken form SA produced 34/48 correct responses. Three months later the performance was 100% correct.

5.16. *Comment*

SA, following a left parietal lesion, suffered from a transient linguistic deficit dominated by phonological impairment and agrammatism. In naming tasks, SA had only minimal impairment in naming objects while she faced severe difficulties in naming actions. The regression analyses did not reveal any frequency effect. Comprehension was good either for nouns and verbs and her ability to mime actions was fully normal. Speech production was agrammatic but not disarthric, consistently with a posterior lesion. The production of verbs in connected speech was not significantly reduced compared to nouns; however, SA presented a clear tendency to produce verbs in infinitive forms. Repetition, writing and reading were impaired because of phonological errors. Comprehension of connected speech was poor with major problems on reversible sentences.

It is not easy to find a coherent interpretation for SA's performances within current lexical access models. In fact, the large amount of phonological errors suggested a deficit at the phonological (lexeme) encoding rather than at the lemma level, hypothesis also supported by the good single word comprehension. However, other data did not allow to identify the locus of the grammatical class effect at the lexeme level: The grammatical class effect was in fact cross-modal (cross-modal dissociation is assumed in the lexical hypothesis Caramazza & Hillis, 1991) and was not observed in transcoding tasks; in addition SA's naming performance was insensitive to frequency (supposed to originate at the lexeme level in Garret's model, Garret, 1988). The sentence context seemed to facilitate the production of verbs compared to tasks of single word production; at the same time, sentence construction was impaired, to a large extent in relation to SA's inability to produce morphologically correct verbs. Sentence comprehension, and in particular reversible sentences comprehension, was impaired consistently with a grammatical deficit.

Ultimately, neither a lemma nor a lexeme deficit fully accounted for SA's grammatical class impairment. At the same time, the data were also contrasting regarding the possibility to establish a definitive cause-effect relation between agrammatism and impaired verb production.

6. Discussion

6.1. *Lexical or semantic locus for grammatical class deficit?*

CG definitely had an isolated semantic memory deficit. In the early stages of the disease the only symptom consisted in word finding difficulties when stimuli repre-

sented objects. Not only names of objects but also proper names were damaged. The ability to name actions was virtually preserved over long time. As already documented (Silveri et al., 1997) naming was significantly better for living than for non-living items. The comprehension tasks proved to be fully normal and the conclusion was that patient suffered from a pure lexical disorder, thus accepting the hypothesis that the lexicon is organised according to semantic class. Some reasons however suggested prudence. Cross-modality analysis did not discover any difference in production tasks (oral and written naming) and no deficit emerged in comprehension tasks. The possibility, also advanced from other authors (Sacchett & Humphreys, 1992; Gainotti et al., 1995) was so accepted that comprehension tasks could not be sensitive enough to discover minimal semantic deficits. This possibility was confirmed. A semantic deficit become more and more evident in later stages. Also in comprehension the more damaged category was the category of non-living. The semantic impoverishment seemed to involve all the categories of meaning to the extent that not only non-living and (mostly in the later stages) living items were impaired, but also other semantic domains such as proper names. When the ability to name and understand names was virtually abolished, the patient was still able to name and understand a large amount of verbs. This pattern of performance would suggest that verbs do not rely, to some extent, to semantic memory if they represent the only class of items preserved in severe semantic impairment such as that of semantic-dementia patients in late stages. At least, we should assume that producing and understanding verbs is not exclusively a function of the semantic memory.

Recently, a distributed model of semantic representation has been proposed that accounts either for semantic categories (in particular animate/inanimate) or grammatical class dissociation (noun/verb) (Bird et al., 2000). This model assumes that the semantic representation of animate nouns, inanimate nouns and verbs forms a continuum of features on a functional/sensory scale: Heavier weighting of sensory features for animate nouns, less for inanimate nouns, and more functional for verbs. Consequently, a damage of sensory features would hamper mostly animate nouns while a damage of the functional features would hamper principally verbs but also inanimate nouns.

Our data may not confirm this hypothesis, since the less damaged category was just the unexpected one (living) in a patient with verb preserved. Our data however, do not disconfirm the assumption that verbs, as inanimate items, are mostly defined by functional features; they simply suggest that verbs may not be represented exclusively within semantic memory, and this may generate exception to Bird et al.'s expectation (2000). Alternatively, we should admit that semantic memory is organised according to broad category of meaning, objects and actions, and that the representation of the actions eludes the degradation of semantic memory being anatomically organised outside the temporal structures. We also mentioned the possibility that, according to a compositional view of verb representation (Breedin & Martin, 1996), a full semantic specification of a verb could rely on semantic variables that are less crucial for the semantic definition of a noun (for example the complexity of the argumental structure). According to this view, the verb could be less sensitive to the breakdown of the semantic memory observed in semantic dementia, representing a semantic dimension at the interface with syntactic aspects of language. This hypothesis however, requires further experimental support.

6.2. *Verb deficit: Syntactic or lexical-semantic*

SA obtained very poor scores in naming actions compared to nouns; however this difference was not confirmed in sentence production, where the same amount of

verbs and nouns was produced. Verbs however, were predominantly produced in infinitive forms. Single word (verb) comprehension was unimpaired but syntactic comprehension was damaged as demonstrated by the low scores obtained in sentence comprehension tasks (mostly on reversible sentences) and in grammaticality judgments.

Thus, the main questions regarding patient SA are as follows:

- Is the poor verb production expression of a deficit of the lexical access that consequently undermines sentence processing, as originally proposed by Saffran et al. (1980)? In this case, at what level of the lexical access, the verb deficit does arise?
- Alternatively, can we admit a primary syntactic deficit, that affects verb production because of a reduced activation of verb-lexical entries during sentence construction?

6.2.1. *Primary lexical access deficit?*

The first hypothesis is discussed within the theoretical ground offered by contemporary models on single word access within more general models of sentence production (Bock & Levelt, 1994; Levelt, Roelofs, & Meyer, 1999). As mentioned in the introduction, according to these models, the first level of lexical access is an abstract representation (lemma) unspecified for phonological and orthographic form, that encodes meaning and grammatical information; the second step is the activation of a phonologically or orthographically specified form. Since grammatical information is assumed to be encoded at the lemma level, we could confirm that SA's verb impairment follows the breakdown of verb-retrieval process at this step of lexical representation (Kim & Thompson, 2000). A deficit at the lemma level would also explain the patient's poor sentence construction to the extent that a lack of grammatical specification may generate insufficient grammatical information to sentence production. The lack of frequency effect in naming would corroborate this view.

The large amount of phonological errors observed in all the production tasks did not allow, however, to ignore an alternative account: The verb deficit is due to a reduced phonological or orthographic specification. A conclusion in favour of a lexeme level of impairment would implicate that the phonological and orthographic lexicons are organised according to grammatical class. However, the verb deficit was cross modal in our patient and did not appear in transcoding tasks, as the phonological access deficit hypothesis assumes. To accept this interpretation, we should also assume that in phonological transparent language such as the Italian language, a single lexicon does exist, independent from phonological or orthographic form and that transcoding tasks might be performed exclusively following a sublexical way.

SA's connected speech was to same extent consistent with the hypothesis of a grammatical impairment secondary to a deficit of verb lexical access and in particular with a deficit of the phonological specification. SA was able to produce as many verbs as nouns in connected speech, even if verbs were predominantly produced in infinitive forms. In other words, SA demonstrated to be able to access the verb lemma level during sentence production while her major difficulty consisted in attributing the morphological form to the selected verbs, and this could generate the agrammatic speech.

6.3. *Primary syntactic deficit?*

SA's sentence comprehension was poor, in particular in semantically reversible sentences and to a lesser extent in morphological sentences. Comprehension of other types of sentences (sentences with semantic alternatives) was less impaired. A

reduced comprehension of reversible sentences suggests a primary syntactic deficit (Schwartz, Saffran, & Marin, 1980). Thus, SA reduced verb production in naming tasks could be interpreted as expression of a central syntactic deficit.

A further observation however, makes the hypothesis of a primary syntactic impairment unlike and reinforces on the contrary the hypothesis of a deficit of the phonological level. SA had poor phonological short-term memory. It has been demonstrated that this component of the memory system is implicated in linguistic operations such as sentence comprehension and phonological encoding (Vallar & Papagno, 1995). Thus, we would not leave out the possibility to search for an explanation that takes into account also the short-term memory, admitting that the verbal short-term memory may contribute to access verb's phonological representation (Marshall, Pring, & Chiat, 1998).

In conclusion, SA's pattern of errors is not fully explained by either of the current hypotheses on lexical access and no finding constrains toward a definitive conclusion.

A different order of interpretations could derive from models that admit parallel activation of lexical-semantic and phonological information and multiple interactions and feedback, as well as the direct inclusion in the models of proper linguistic components that have been traditionally considered as discrete cognitive systems such as the phonological short-term memory. Thus, the verb-class impairment in patients with phonological deficit could receive an account by admitting a reduced activation between the lemma level, where the items are supposed to receive syntactic definition, and the level where the abstract representation of the word receives phonological specification (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997). In this model it is explicitly admitted that a syntactically specified lemma could be influenced by phonological relations. Within a spreading activation model, the phonological short-term memory could be responsible of the maintenance of adequate level of activation at the phonological level (Martin, 1996).

7. Conclusion

The finding of patients that obtained opposite results with the same tests definitely rejects the artefactual nature of the grammatical class effects. The data also support the hypothesis that a noun retrieval impairment is proper of anomia patients while a verb retrieval deficit is found in subjects who present difficulties in sentence construction, not only typical non-fluent agrammatics but also fluent paragrammatic patients. The data are also consistent with previous clinical evidence that assigns to temporal structures the processing of nouns and to the frontoparietal structures the processing of verbs.

A deficit for nouns seems definitely expression of a semantic-lexical impairment; therefore as a deficit at the lemma level within current theories of lexical access or as expression of a semantic degradation of objects within a theory assuming the semantic memory organised according to semantic categories. On the contrary, the verb deficit may express impairment at different level of linguistic organisation, thus not only semantic, but also probably phonological and syntactic. The semantic deficit observed in semantic dementia may spare to some extent verbs (see also patient described by Breedin, Saffran, & Coslett (1994)); this suggests two possibilities: First that verb is not only defined by semantic features; second that verb's semantic dimension is to some extent different from noun's semantic dimension, for example, the knowledge of the thematic roles may be crucial for verbs but not for nouns. A further possibilities does exist: That noun and verb are represented in segregated

cerebral areas, temporal vs frontal, as originally hypothesised by Gainotti et al. (1995) so that semantic dementia that specifically involves temporal structures may spare verbs knowledge. However this is only a restatement of the conclusion that the class of verbs, “represented” in frontal structures is related to the production of connected speech, in other words to syntactic aspects of language. Similarly, evidence of a parietal lesion in patients with verb production would trace back to phonological-morphological aspects of verb encoding and sentence construction.

The pattern of performance obtained in SA allows rejecting the possibility that she could suffer from a semantic deficit but it is not fully consistent with either of the current models of lexical access. Similarly, no definitive conclusion may be drawn on the relationship between deficit for verbs and impaired sentence construction. Further experimental evidence is therefore necessary to identify the various functional loci of the verb impairment, to which, partially at variance with noun impairment, multiple contribution within the various level of language organisation must be hypothesised.

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