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Research report

Verb comprehension and naming in frontotemporal degeneration: The role of the static depiction of actions

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ABSTRACT

We report the case study of a patient JB with the frontal variant of frontotemporal dementia (fv-FTD), who was disproportionately impaired in naming and comprehending verbs in comparison with nouns. We examined to what extent the patient's verb disproportionate deficit was dependent on the type of stimuli used to assess verb processing, that is, static depictions of actions, videotaped actions, or verbal stimuli. We found that the verb disproportionate deficit JB presented when her naming or comprehension was assessed from static depictions of actions (i.e., photographs) disappeared when naming or comprehension was assessed from videotaped actions or verbal stimuli. These results indicated that JB did not present disproportionate difficulties with *verb* processing *per se* (i.e., with retrieving the lexical and semantic features of verbs). Instead, the seemingly disproportionate verb deficit found in JB – and possibly also in other previously reported patients with executive resource limitation – was likely due to the picture stimuli used to probe verb versus noun naming and comprehension not being equal in executive resource demands. The finding of this study thus underscores the need of considering carefully the specific effects of task and type of stimuli in the patients' performance with action pictures before making theoretical claims about the noun versus verb or object versus action lexical and semantic representation in the brain.

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1. Introduction

The production and comprehension of words from different grammatical classes such as nouns and verbs may be differentially impaired in patients with focal brain lesion or degenerative brain disease. Numerous studies have described aphasic patients showing either a disproportionate impairment in producing verbs in comparison to nouns or the opposite pattern, a disproportionate impairment in producing nouns. These reports of double dissociations between noun and verb naming are a fruitful source of evidence for the issue of how lexical knowledge and, in particular, grammatical word class is represented in the human brain (see for recent review and discussion, Shapiro and Caramazza, 2003).

Whether the grammatical class specific deficits described in patients with Dementia of Alzheimer's type (DAT) or Frontotemporal Dementia (FTD) have empirical relevance for theories of lexical knowledge representation is less clear. Although

some DAT individuals were reported who named verbs better than nouns (Parris and Weekes, 2001; Robinson et al., 1999), the pattern commonly observed in group studies of DAT or FTD patients was a disproportionately impaired performance with verbs in comparison to nouns (e.g., Bak et al., 2001; Cappa et al., 1998; Hillis et al., 2002; Rhee et al., 2001; Robinson et al., 1996; Silveri et al., 2003; White-Devine et al., 1996). This pattern has been accounted for by reference to the semantic or linguistic disorders which are part of these pathologies. Thus, verbs would be more vulnerable than nouns to the degradation of semantic memory which is typically found in DAT (Hodges et al., 1992) because of the semantic features and relations composing the verb meanings being more sparse and less redundant (Robinson et al., 1996; White-Devine et al., 1996). In FTD patients, the disproportionate verb naming deficit would be caused by impaired processing of the morphosyntactic features of verbs (Bak et al., 2001; Cappa et al., 1998) in the context of morphosyntactic difficulties due to frontal cortical involvement (Snowden et al., 1996).

However, the findings of the more recent studies by Rhee et al. (2001) and Silveri et al. (2003) invite one to consider in a different light the reports of verb disproportionate deficits in demented patients. Both Rhee et al. and Silveri et al.'s studies provided evidence for a significant correlation between a disproportionate deficit in verb naming (Silveri et al., 2003) or verb comprehension (Rhee et al., 2001) and executive resource limitation in DAT and FTD patients. In both patients with DAT and the frontal variant of frontotemporal dementia (fv-FTD), performance in verb naming significantly correlated with performance in the Stroop Test and Backward Digit Span (Silveri et al., 2003). Relatively worse performance with verbs than nouns in word–picture matching significantly correlated with performance in Stroop, category naming fluency, and Trails B tests in FTD patients (Rhee et al., 2001). Such correlation especially showed up in patients with fv-FTD, who presented the greatest discrepancy in performance between verb and noun comprehension and the more severe limitation of executive resources (Rhee et al., 2001). These findings thus suggest that verb processing may demand more executive resources than noun processing. Given the reduction of executive efficiency which is commonly part of dementia syndromes, it is thus likely that executive resource limitation contributes to the disproportionate verb deficits found in dementia patients, or even could be, in some cases, the mere underlying cause of such disproportionate deficit.

In which way could executive resource limitation impair the comprehension and naming of verbs more than nouns? Rhee et al. (2001) and Silveri et al. (2003) suggested that verb comprehension and naming may be more dependent on executive resources than noun because verb processing requires one to access and manipulate a more elaborate set of semantic and linguistic informations. Thus, executive resources such as working memory, planning, selective attention, and inhibitory control would be crucial to coordinate the correct use of all aspects of a verb representation, that is, its grammatical and thematic features further to its semantic features.

However, the evidence in Rhee et al. and Silveri et al.'s studies is ambiguous as to the processing level or mechanism that could be affected by the limitation of executive resources. In these studies, noun and verb naming and comprehension were assessed exclusively with tasks involving pictures of objects (for nouns) and static pictures of actions (for verbs). Thus, in Rhee et al.'s study, the results were based on a single comprehension task, a word–picture verification task, in which the patients were asked to tell whether the word (a noun or a verb) written beneath a picture (depicting an object or an action) was the correct one for that picture. Silveri et al. assessed nouns and verbs in DAT and FTD patients with two tasks, a picture naming and a two-choice word–picture matching task, but both involved objects and actions depicted as line-drawn figures. In both studies, no attempt was made to control for the relative processing difficulty of drawings of actions compared to drawings of objects (although we admit that such a control might be unfeasible).

Yet there are a number of factors that are likely to make drawings of actions more difficult to process than drawings of objects. First, drawings of actions are likely to have higher perceptual complexity than drawings of objects. Second, the task of recognizing drawings of actions is probably less frequently performed in everyday settings than recognizing drawings of objects. Third, in drawings of actions, crucial information for the recognition of the action, like the temporal and movement features of the action, is lacking (Fung et al., 2001). While the factor of visual complexity is expected to affect mainly the performance of patients with visuoperceptual impairment, the factors of task familiarity and stimulus informativeness are likely to have significant effects on the performance of patients with reduced executive resources like the patients in Rhee et al. and Silveri et al.'s studies. Dealing with novel stimuli and/or tasks (Norman and Shallice, 1986) and recovering lacking information both should engage non-routine, controlled processing mechanisms demanding of executive resources.

Therefore, the issue is raised whether the processing level that is sensitive to the amount of executive resources available is the lexical–semantic level, as proposed by Rhee et al. and Silveri et al., or rather the pre-semantic processing mechanisms involved in recognizing objects and actions from (static) drawn depictions of them. In other words, is it verb processing per se that is more demanding of executive resources than noun processing or, instead, the recognition of actions from static depictions compared to the recognition of objects from pictures?

The purpose of this single case study was to clarify the role of stimuli such as static depictions of actions in the disproportionate verb deficit presented by an fv-FTD patient (JB) in a picture naming and a word–picture verification task. In that perspective, JB's verb and noun processing was further assessed with tasks not involving picture stimuli as well as in a naming task eliciting verbs from videotaped actions instead of static pictures of actions.

2. Case report

JB, a right-handed woman with 8 years of formal education, was 75 years old in November 2003, when this study started. The diagnosis of FTD was established in May 2002. At that time, the patient's spouse took her to the hospital for examination where he reported she claimed he was not her

husband, he was a double (Capgras delusion; Ellis and Lewis, 2001). The neuropsychological examination (see Table 1) revealed a dysexecutive syndrome without memory, praxic, or language impairment (MMSE = 28/30) and the CT-scan showed a significant atrophy of the temporal and posterior frontal regions. In October 2002, MRI confirmed a significant atrophy of the temporal and posterior frontal regions, more marked in the left than the right hemisphere (see Fig. 1). Between October 2002 and November 2003, the patient's condition evolved towards marked word-finding difficulties in spontaneous speech, temporal disorientation, attentional deficits, and behavioural disorders such as apathy, distractibility, mood swings, and stereotypical behaviours. JB did not participate in the housework any more, was not any more able to wash and dress herself, to go shopping, to prepare a meal, or to use money.

In November 2003, the neuropsychological examination (see Table 1) revealed a deterioration of JB's cognitive status (MMSE = 20/30). Her short- and long-term recognition memory was within the normal range, but her performance in long-term recall memory was at floor. Her performance on the Rey Figure was poor and, at the Clock Test, her spontaneous drawing showed perseverations, lack of planning, and misses of the hands of the clock. Part A of the Trail Making Test showed slow performance and Part B had to be interrupted due to JB's difficulty to alternate a letter and a number as well as the frequent need to remind her the task instructions. Category and letter naming fluency were severely impaired. On the whole, these tests showed cognitive slowing and impairments in planning, flexibility, and attention.

Extensive language screening essentially revealed severe word-finding difficulties in spontaneous and narrative speech. However, object picture naming and word-to-picture matching (LEXIS; de Partz et al., 2001) were within the normal range: JB scored 57/64 (89%) at the picture naming task and 63/64 (98%) at the word-to-picture matching task (controls' mean score in naming: 57.9/64, 90%; in matching: 60.7/64, 95%). Repetition of syllables, words, and sentences was preserved, except for one complex sentence. Reading aloud pseudowords, regular words, and irregular words as well as writing words and sentences on dictation were also spared. Comprehension of spoken sentences as assessed by the Token Test (de Renzi and Vignolo, 1962) was within the normal range but was impaired for passive reversible sentences in a sentence-to-picture matching task.

In sum, the neuropsychological and language examination carried out in November 2003 essentially revealed severe word-finding difficulties in spontaneous speech, impaired verbal long-term memory and executive deficits. An MRI scan performed in May 2004 confirmed the bilateral frontotemporal lobe atrophy (see Fig. 1).

3. Experimental investigations: general method

The experimental investigations were carried out from November 2003 to June 2004 in several sessions of 60–90 min. Every task presented to JB was presented to a sample of control subjects, which was different across the tasks, and constituted from a pool of 43 subjects as closely matched as possible to the patient for age (mean age = 72.3) and education (mean number of years = 10.7). Depending on the task, the control sample included 5–11 subjects.

Crawford and Howell's (1998) modified t-test was used for testing whether the patient's performance for nouns and verbs was significantly impaired in comparison to the control group's performance (test for the presence of a deficit) and Crawford and Garthwaite's (2005) Revised Standardized Difference Test (RSDT) was applied for testing whether the discrepancy between nouns and verbs in the patient's performance was significantly different from the noun/verb discrepancy observed in the performance of the control group (test for the presence of a dissociation).

These statistical methods have been recently developed by Crawford and colleagues for the statistical analysis of single case data in neuropsychology. The modified t-test allows us to compare a single test score obtained from an individual with a control sample that has a small N. It overcomes the disadvantage of the standard z-score method, which exaggerates the rarity/abnormality of an individual's score and inflates the Type I error rate, by treating the statistics of the control sample as statistics rather than as population parameters and using the t-distribution (with $n - 1$ degrees of freedom) rather than the standard normal distribution. Essentially, this method is a modified independent samples' t-test in which the individual is treated as a sample of $M = 1$. The RSDT, which is in essence a modified paired samples' t-test, is a stringent test for the presence of a dissociation. It compares the difference between two tasks observed for a patient with the distribution of differences in the control sample. The scores on the two tasks are standardised, that is, the individual's performance on tasks X and Y is expressed as z scores based on the mean and SDs of the control sample. This t-test overcomes the difficulties linked to the widely used within-patient data analysis based on the chi-square test. First, the assumption of independence, required for a chi-square test, is violated in these circumstances. Second, and more importantly, it was found that the within-subject approach yielded numerous false positive indications of a dissociation in patients who exhibited differences between the number of living and non-living items named (Laws et al., 2005); the opposite pattern was also found, that is, patients whose chi-square results were not significant showed strong evidence of a dissociation when their naming was referenced to control performance.

Finally, it is worth noting that Monte Carlo simulation showed that the Type I error rate was kept minimal with Crawford and Howell's (1998) modified t-test even in the face of extreme skewness and leptokurtosis (ceiling performance) in the control distribution (Crawford et al., 2006). Crawford and Garthwaite's RSDT, which tests for the presence of a dissociation, was also found to limit Type I error rate even in the face of extreme skewness (Crawford and Garthwaite, 2005).

4. Assessing noun and verb naming and comprehension with picture stimuli

In order to assess JB's noun and verb naming and comprehension, a picture naming task and two word comprehension tasks, i.e., a word–picture verification task and a multiple-choice

Table 1 – JB's results at the neuropsychological exams performed in May 2002 and November 2003			
	JB		Control subjects
	May 2002	November 2003	
Digit Span			
Forward	5	5	5.67 (1.11)
Backward	4	4	4.07 (1.11)
Door Test (Baddeley et al., 1994)			
Part A	9/12 (p. 10–25)	11/12 (p. 75)	
Part B	Interrupted	1/12 (p. 1)	
		Total: 12/24 (p.10)	
RL/RI-16 (Van der Linden et al., 2004)			
Immediate recall	15/16	13/16	15.3 (.80)
Free recall 1	3/16	2/16	7.68 (2.18)
Cued recall 1	9/16	9/16	
Total recall 1	12/16	11/16	
Free recall 2	8/16	1/16	8.95 (2.27)
Cued recall 2	8/16	11/16	
Total recall 2	16/16	12/16	
Free recall 3	7/16	1/16	10.13 (2.23)
Cued recall 3	9/16	10/16	
Total recall 3	16/16	11/16	
Delayed recall	9/16	0/16	10.35 (2.20)
Cued delayed recall	7/16	10/16	
Recognition	15/16 (p. 5–25)	16/16 (p. 25–100)	
Picture naming (LEXIS)	57/64	51/64	57.9 (4.97)
Word-to-picture matching (LEXIS)	n.a.	63/64	60.7 (1.49)
Attention: ''Trois matrices''	43/60	35/60	41.59 (9.61)
Attention: code (Wechsler, 1989)	49 (s.n. 11)	22 (s.n. 8)	
Clock Test			
Order		2/10	
Copy		9/10	
Stroop Test		n.a.	
Naming			
Time	101 sec		71.87 (13.81)
Self-corrected errors	2		1.03 (1.22)
Uncorrected errors	1		
Reading			
Time	68 sec		49.53 (11.7)
Interference			
Time	328 sec		150.37 (39)
Self-corrected errors	6		3.79 (4.9)
Uncorrected errors	3		
Trail Making Test			
Part A	43 sec	121 sec	83.06 (34.35)
Time	Interrupted after 295 sec	Interrupted after 350 sec	157.65 (56.61)
Errors	3		
Part B	n.a.	n.a.	
Category fluency	n.a.		
Animals		5	26.5 (6.30)
Fruit		2	17.12 (5.11)
Letter fluency ''R''	n.a.	2	17.25 (5.20)
Token Test (de Renzi and Vignolo, 1962)	n.a.	30/36	31.31 (3.48)
Non-verbal reasoning: PM 38	29 (p. 75)	n.a.	
Rey Figure (Rey, 1959)	n.a.		
Copy			
Time		7 min (p. 10)	
Accuracy		30.5/36 (p. 10–25)	

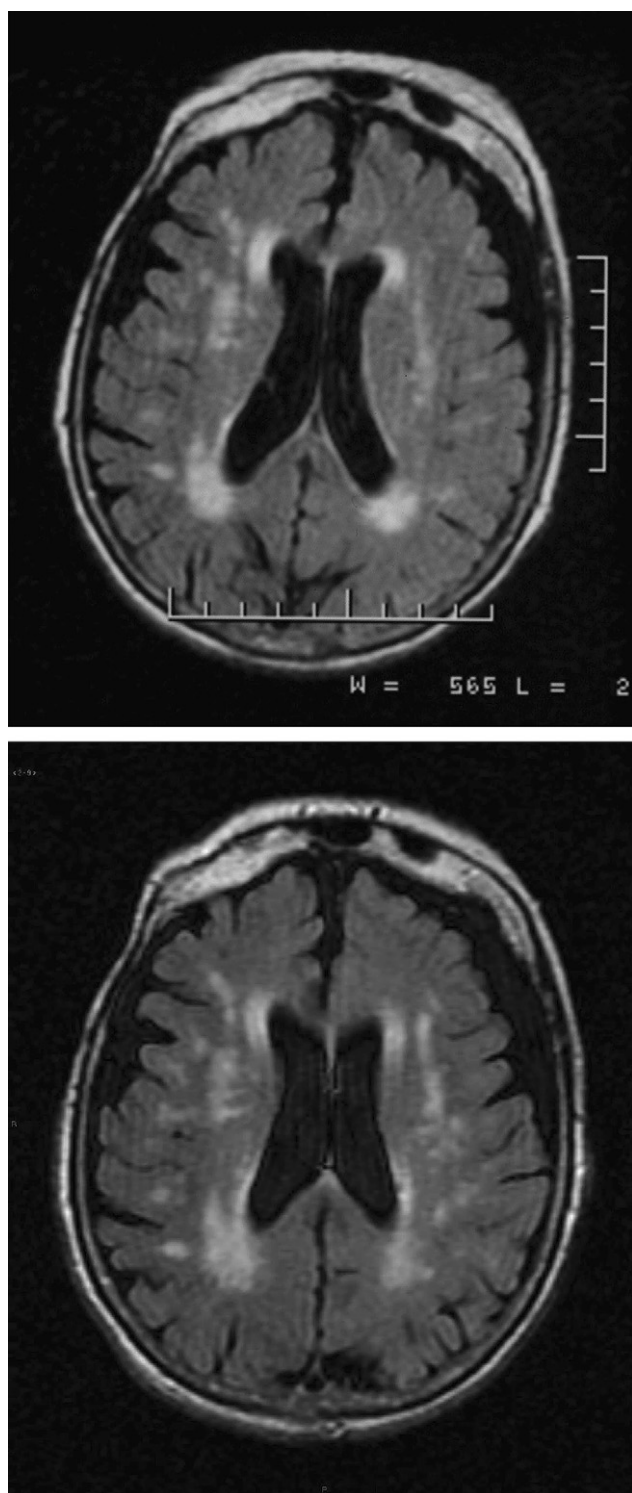n.a. = not administered, s.n. = standard note.

Fig. 1 – MRI images of JB in October 2002 (top) and May 2004 (bottom).

word-to-picture matching task, were prepared with colour photographs and the same set of items.

4.1. Material

One-hundred and eight items were selected. Half of them (54) were nouns from various semantic categories (animals, vegetables, body parts, food, tools and other artefacts) and the other half were verbs denoting various kinds of actions (motion, interactions between two human beings, transitive actions with or without an instrument, actions performed by an animal, and events including objects only). The 54 nouns and 54 verbs were matched for objective and subjective word frequencies and concept familiarity (see Table 2).

A colour photograph was selected for representing each object and action with no or a minimal context. Most of the photographs for actions were drawn from Fiez and Tranel (1997). For both the comprehension tasks (word–picture verification and word-to-picture matching), three additional photographs per item were selected as foils: one corresponding to a "close" semantic coordinate of the item, one to a "far" coordinate of the item, and one that was not semantically related to the item. For example, for the item *vélo* (bike), the photographs of a scooter and of a train were selected as the "close" and "far" semantic foil, respectively, and the photograph of an apple was selected as the unrelated foil. For the item *éternuer* (sneezing), the "close" semantic foil was a photograph of somebody blowing her nose, the "far" semantic foil, a photograph of someone washing herself, and the unrelated foil was a photograph of someone eating.

Because the closer a foil is to the target the more difficult it should be to reject it, we checked the semantic relatedness between targets and foils in both grammatical classes. A group of 26 subjects (age = 25–60) were presented with the 324 target-foil pairs as written words and asked to rate on a five-point scale how semantically related was each pair of words (1 = very low relatedness, 5 = very high relatedness). The semantic relatedness between the targets and the "close" semantic foils, and between the targets and the "far" semantic foils, both turned out to be rated *lower* for verbs than nouns (see Table 3) which, if anything, should make the verb foils easier to reject than the noun foils and, hence, the comprehension tasks easier for verbs than nouns.

4.2. Procedure

In the picture naming task, JB was asked to provide the spoken and, in another session, the written name of the object or

Table 2 – Objective word frequency, subjective word frequency, and concept familiarity for the 54 nouns and 54 verbs of the naming and comprehension tasks with colour photographs

	Nouns	Verbs	t-Tests
Objective frequency[a]	23.93	33.04	$t(106) = -1.45$, $p = .14$
Subjective frequency[b]	3.09	3.02	$t(106) = .41$, $p = .64$
Concept familiarity[c]	3.25	3.08	$t(106) = .29$, $p = .25$

a Printed frequency per 100 million occurrences (Content et al., 1990).
b Rated on a five-point scale (1 = low frequency, 5 = high frequency) by 25 subjects for half of the items and 29 subjects for the second half (mean age of the 54 subjects = 66, SD = 8.9).
c Rated on a five-point scale (1 = low familiarity, 5 = high familiarity) by 27 subjects for half of the items and 26 subjects for the second half (mean age of the 53 subjects = 67, SD = 9.7).

Table 3 – Mean semantic relatedness between the targets and the close and far semantic foils in the word–picture verification and the word–picture matching task			
	Nouns	Verbs	t-Tests
Close semantic foil	4.12	3.47	t (106) = 5.61, p < .001
Far semantic foil	2.96	2.35	t (106) = 5.39, p < .001

action depicted in the 108 photographs. At every noun trial, the examiner prompted the patient's response with the question "What is this?" and at every verb trial, with the question "What is s/he doing?" or "What is happening?" (depending on the actions/events including an animate agent or not). Presentation of the verb and noun trials was alternated in an ABBA design applied through four sessions. JB was presented the spoken picture naming task three times, with a period of 4 months between the first and the second presentation and 2 months between the second and the third (that is, in November 2003, March 2004, and May 2004).

In the word–picture verification task, each item was presented as a spoken or written word, once with the correct photograph, once with the "close" semantic foil, once with the "far" semantic foil, and once with the unrelated foil. The patient was asked to tell whether the word was the correct name for the object or the action depicted in the photograph. An item was scored as correct when the patient both accepted the correct picture and rejected the three foils. Thus the chance level for percentage of correct responses in this task was 6.25% (1/2 × 1/2 × 1/2 × 1/2 = 1/16). The spoken and the written version of the task were presented in several sessions and the verb and noun items were alternated with an ABBA design. The spoken word–picture verification task was presented twice with a period of 6 months separating the first from the second presentation (that is, in November 2003 and May 2004).

In the word-to-picture matching task, the same photographs (targets and foils) used in the word–picture verification task were arranged so as to measure word comprehension with a multiple-choice task. In this case, the patient was presented with a spoken word and four pictures simultaneously: the picture corresponding to the spoken word, the "close"

semantic foil, the "far" semantic foil, and the unrelated foil (for a given item, the three foils were the same as the ones presented one at a time in the word–picture verification task). She was asked to point out the picture that corresponded to the spoken word. As the patient had to point out one picture among an array of four, the chance level for percentage of correct performance was here 25% (1/4). The noun and verb items were presented again within an ABBA paradigm. JB was presented this task once, in May 2004.

4.3. Control samples

The picture naming task was presented to 11 control subjects (mean age = 72.2, mean number of years of education = 13.8). Among them, 10 subjects also performed the word–picture verification task (mean age = 70.2, mean number of years of education = 12.8). The word-to-picture matching task was presented to a different sample of 5 subjects (mean age = 68.8, mean number of years of education = 9).

4.4. Results

JB's and the controls' results in the various tasks, output modalities, and presentations are displayed in Fig. 2. Averaged across the various modalities and presentations of the picture naming task, JB's scores were 76% (41/54) for the nouns and 41% (22/54) for the verbs, while the controls' mean scores were 97% (52.4/54, SD = .28) and 93% (50.1/54, SD = .49), respectively, for nouns and verbs. The data analyses indicated that JB's naming performance was significantly impaired, in comparison to the controls', for both nouns and verbs, in both spoken and written naming, and across the three presentations [Crawford and Howell's (1998) modified t-test: −72.47 < t (10) < −18.33, all p < .0001]. However, a test on the standardized difference between nouns and verbs, which compared the difference between verbs and nouns observed for JB with the distribution of differences in the controls, showed that JB's naming performance was significantly more impaired for verbs than nouns, in both spoken and written naming and at the three presentations [Crawford and Garthwaite's (2005) RSDT: 5.81 < t (10) < 13.59, .0001 < p < .005]. At the three
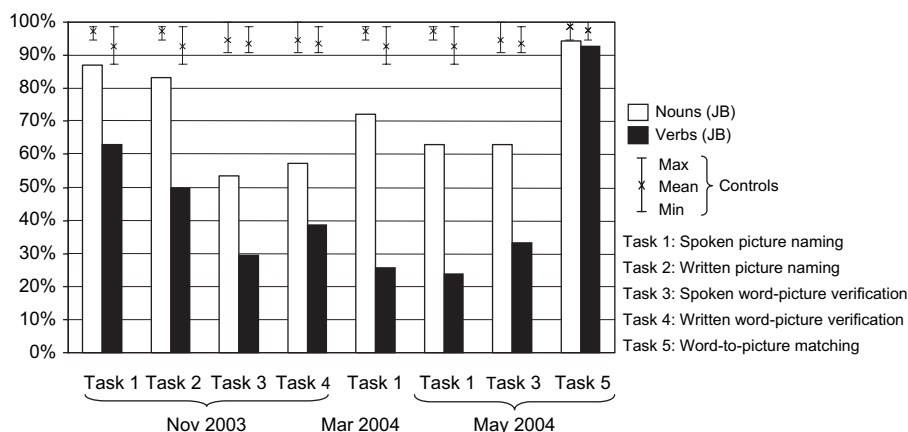

Fig. 2 – JB's and controls' percentage of correct responses for nouns and verbs in the picture naming, word–picture verification and word-to-picture matching tasks.

presentations, JB's naming errors consisted mainly in semantic errors, circumlocutions, and non-responses, for both verbs and nouns. There was no error consisting in producing a noun when a verb was required neither the reverse. Moreover, in circumlocutions, it was evident that JB tried to describe an action when presented with an action photograph and an object when presented with an object photograph.

In the word–picture verification task, the same pattern of results was obtained as in the picture naming task. JB's scores averaged across the spoken and written modalities and across both presentations were 57% (31/54) for nouns and 33% (18/54) for verbs. The controls' mean scores were 95% (51.1/54, SD = .43) and 93% (50.3/54, SD = .45) for nouns and verbs, respectively. The data analyses indicated that JB's performance was significantly impaired, in comparison to the controls', for both nouns and verbs, in both the spoken and written modalities, and at both presentations [modified t-test: $-72.68 < t (9) < -37.92$, all $p < .0001$] but a test on the standardized difference between nouns and verbs indicated that, in comparison to the controls', JB's word comprehension was significantly more impaired for verbs than nouns, both for spoken and written words and at both presentations [RSDT: $13.67 < t (9) < 20.68$, all $p < .0001$]. It is worth noting that, even if JB's performance in this task was very poor compared to the controls, a non-parametric binomial test indicated that her performance was significantly above the chance level ($p < .0001$). That her responses were not random was indicated also by her errors only rarely consisting in accepting the unrelated foil (5.4% of the errors for nouns and 12.6% of the errors for verbs).

The results from the word-to-picture matching task showed a very different pattern. In this task, JB's accuracy was high for both nouns and verbs: she scored 94% (51/54) and 93% (50/54) while the controls scored 99% (53.2/54, SD = 1.30) and 97% (52.6/54, SD = 1.34), respectively, for nouns and verbs. The data analyses revealed that JB's performance was not significantly impaired in comparison with controls, either for nouns [modified t-test: $t (4) = -1.54$, $p = .1$] or verbs [modified t-test: $t (4) = -1.77$, $p = .07$]. The test on the standardized difference between nouns and verbs indicated that the discrepancy between nouns and verbs was far from reaching significance [RSDT: $t (4) < 1$].

4.5.   Discussion

The results of this first set of experiments showed that JB was disproportionately impaired in naming and comprehending verbs in comparison with nouns in a picture naming and a word–picture verification task.[1] This pattern of performance closely parallels the pattern reported by Cappa et al. (1998), Rhee et al. (2001), and Silveri et al. (2003) in groups of FTD patients examined with tasks very similar to those used here. Thus, the group of 10 FTD patients in Cappa et al.'s study and of 17 fv-FTD patients in Silveri et al.'s both showed

significantly poorer performance for verbs than nouns in a picture naming task. Rhee et al., who examined a group of 21 patients with FTD, found that they were significantly more impaired with verbs than nouns in a word–picture verification task. Interestingly, Silveri et al. presented to their patients a two-choice word-to-picture matching task in addition to the naming task but, contrary to the results obtained in naming, found no reliable difference between nouns and verbs in the matching task. This was just the pattern observed in JB, who did not performed differentially for verbs and nouns in the multiple-choice matching task. Furthermore, the results showed that JB's verb disproportionate deficit was present in both the spoken and the written modalities of naming and comprehension and remained significant across time (7 months) in spite of the decrease of performance noted for both nouns and verbs during the same period. This suggests that JB's verb disproportionate deficit in picture naming and word–picture verification was due to a permanent and strong factor exerting its effect over and above the potential fluctuations in performance due to variable attention, memory, or other executive resources and the general decrease of performance due to the disease progression. Finally, the results indicated that JB was impaired not only in accessing the phonological and orthographic forms of words (both nouns and verbs) for production, as it was already apparent from her frequent word-finding failures in spontaneous speech, but also in recovering and/or manipulating the meanings of nouns and verbs, at least in a task like the picture–word verification.

The absence of impairment in the multiple-choice comprehension task might be due to that task being less sensitive in identifying deficits in retrieving word meaning than the word–picture verification task, as demonstrated by Breese and Hillis (2004). In addition, in the multiple-choice comprehension task, a subject's response might hinge upon more automatic mechanisms than in the verification task. In the multiple-choice task, the correct picture is present on each trial. Hence, because of the strength of the stimulus-response (spoken word–visual representation of its referent) association in memory, pointing out the correct picture rather than the closely related foil would rely on more automatic processes than rejecting the closely related foil in the verification task, which requires reaching the decision of rejection in the absence of a more strongly associated word–picture pair. Importantly, JB's normal performance in the multiple-choice comprehension task suggests that she was not impaired in the visual processing of pictures of objects or actions and, hence, that her erroneous responses in the verification task indeed were due to difficulties in recovering and/or manipulating lexical–semantic information about nouns and verbs.

In sum, the results of the experimental investigations so far showed that JB was disproportionately impaired in naming verbs in comparison to nouns, that this grammatical class effect was reliable across the spoken and written modalities and across time, and unlikely an artefact of word frequency and concept familiarity. A disproportionate verb deficit was also found in a comprehension task, the word–picture verification task, which could not be ascribed to artefacts of word frequency, concept familiarity, or the semantic distance between the target and the foils. The next part of the experimental

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[1] According to Shallice's (1988) distinction between classical and strong dissociation, JB showed a "strong dissociation" in her performance with verbs and nouns in these tasks: both nouns and verbs were significantly impaired but verbs were significantly more impaired than nouns.

investigations was devoted to test for the role of picture stimuli in JB's disproportionate verb deficit.

5. The role of static depictions of actions in JB's verb disproportionate deficit

In order to determine to what extent using static pictures of action as stimuli in the naming and the word–picture verification tasks could have been responsible for her disproportionate verb deficit, JB's noun and verb production was evaluated in connected speech, in two word comprehension tasks (a synonym pointing task and a semantic association task) that comprised written word stimuli only and, finally, in a verb naming task from videotaped actions. These tasks were presented to JB in May 2004.

5.1. Noun and verb production in connected speech

5.1.1. Procedure

Connected speech samples were tape-recorded from free conversations with the patient and 5 control subjects (mean age = 74.7, mean number of years of education = 9) and then transcribed in standard orthography. The corpus submitted to the analyses comprised the first 300 words of each subject's speech sample. Following Mayer and Murray's (2003) guidelines, repeated words, unintelligible words, and non-word fillers (e.g., euh) were excluded from the count of these 300 words. Then, the number of nouns and verbs produced and the number of word-finding episodes affecting nouns and verbs were counted in each subject's corpus. The auxiliaries être (to be) and avoir (to have) and the verb être (to be) when used in the form c'est (it is) were not counted as verbs. Pronouns and numerals were not counted as nouns (Segalowitz and Lane, 2000). Noun and verb word-finding episodes included words immediately preceded by a prolonged hesitation (more than 2 sec), words preceded or accompanied by comments indicating difficulty, self corrections, paraphasias, or omission of a word in a sentential context (Mayer and Murray, 2003).

5.1.2. Results

As displayed in Table 4, JB produced very few tokens of nouns in connected speech in comparison to the control subjects, while her production of verb tokens was quantitatively within the control range. The data analyses indicated that the number of verb tokens was not significantly different between JB's and controls' speech samples [modified t-test: $t(4) = -1.51$, $p = .10$] whereas the number of noun tokens was significantly lower in JB's samples [modified t-test: $t(4) = -2.21$, $p < .05$]. However, the difference between the number of noun and verb tokens in JB's speech samples was not significantly different from that found in controls' speech samples [RSDT: $t(4) < 1$]. Likewise, the token noun/verb ratio in JB's speech sample (.25), albeit lower than the average ratio found in the controls' samples (.99, SD = .34), did not significantly differ from it [modified t-test: $t(4) = -1.99$, $p = .12$]. Finally, episodes of word-finding difficulties occurred significantly more often for nouns than verbs in JB's speech ($\chi^2 = 18.64$, $p < .0001$).

Thus, in connected speech, no evidence was found for a disproportionate verb impairment and, in fact, there was a trend towards the opposite direction. However, this relative sparing of verb production in connected speech might be due to the verbs used in everyday conversation tending to be of higher frequency than nouns (for a similar point in relation to the analysis of the speech of patients with semantic dementia (SD), see Bird et al., 2000). We thus checked the average frequency of the nouns and verbs produced by the controls and JB, using spoken word frequency norms based on movie dialogues (New et al., 2005). In the controls' speech samples, it turned out that the verbs produced indeed were, on average, of higher frequency than the nouns [$t(8) = 9.49$, $p < .0001$] and the same pattern was found in JB's samples [$t(43) = 2.25$, $p < .05$]. The discrepancy between the frequency of the nouns and the verbs produced by JB was not significantly different from the noun/verb frequency discrepancy found in the controls' speech samples [RSDT: $t(4) = 1.10$, $p = .33$]. In this context, both the failure to find a verb disproportionate deficit and the trend towards a relative preservation of verbs in JB's connected speech cannot be given a definite interpretation. Nonetheless, it is worth noting that the verbs JB produced were all correctly inflected and used within a correct argumental structure, which indicated that, at least for high-frequency verbs, she was able to retrieve and correctly use their phonological, thematic, and morphosyntactic features in connected speech.

Table 4 – Characteristics of JB's and control subjects' connected speech samples											Noun/verb ratio	
	Nouns					Verbs						
	Nr token	Nr type	TTR[a]	Nr WFE[b]	Frequency[c]	Nr token	Nr type	TTR[a]	Nr WFE[b]	Frequency[c]	Token	Type
JB	9	8	.89	11	347	36	19	.53	2	7071	.25	.42
Controls												
Mean	44	30.4	.70	–	223	44.8	23.6	.53	–	6736	.99	1.31
Min	26	17	.60	–	169	37	21	.43	–	4718	.60	.65
Max	58	38	.84	–	320	51	26	.60	–	8995	1.41	1.72
SD	14.4	8.8	.09	–	57.2	5.3	2.3	.06	–	1533	.34	.45

a Type token ratio.
b Word-finding episodes.
c Mean spoken word frequency from movie dialogues (New et al., 2005).

5.2. Synonym pointing task

5.2.1. Material and procedure

The synonym pointing task comprised 120 items: 60 nouns and 60 verbs matched for written word frequency (see Table 5). The noun and verb sets each comprised 30 concrete and 30 abstract words. Each item was presented as a cue (written) word together with two other words written below it. JB was asked to point out the word that was the best synonym for the cue word. Each item was presented twice, once with a synonym and a semantically related (but not synonym) word [e.g., sortilège (spell) – envoûtement (bewitchment) – magie (magic)], and once with a synonym and an unrelated word (e.g., sortilège (spell) – envoûtement (bewitchment) – mollesse (softness)]. An item was scored as correct when the patient choose the correct synonym on both presentations. The chance level for percentage of correct responses thus amounted here to 25% ($1/2 \times 1/2 = 1/4$).

5.2.2. Control sample

The synonym pointing task was administered to 9 control subjects (mean age = 74.2, mean number of years of education = 8).

5.2.3. Results

JB scored 52% (31/60) and 45% (27/60) for the nouns and verbs, respectively, while the average scores of the controls were 98% (58.7/60, SD = 1.12) for the nouns and 97% (58.3/60, SD = 1.32) for the verbs (see Fig. 3). JB's performance was significantly impaired for both verbs [modified t-test: $t(8) = -23.44$, $p < .0001$] and nouns [modified t-test: $t(8) = -22.52$, $p < .0001$]. Although her raw score for verbs was slightly lower than her score for nouns, no significant dissociation between verbs and nouns was observed [RSDT: $t(8) < 1$]. Although her performance was very poor compared to the controls, a non-parametric binomial test showed that it was significantly above the chance level for both verbs ($p = .001$) and nouns ($p < .001$).

5.3. Semantic association task

5.3.1. Material and procedure

The 52 triplets of nouns from the "Pyramids and Palm Trees Test" (PPT, Howard and Patterson, 1992) and the 52 triplets of verbs from the "Kissing and Dancing Test" (KDT, Bak and Hodges, 2003) were translated in French. The 52 triplets of nouns were matched in written word frequency (New et al., 2004) with the 52 triplets of verbs [$t(101) < 1$]. Each triplet

Table 5 – Mean word frequency and imageability of the nouns and verbs in the synonym pointing task

	Nouns	Verbs	t-Tests
Frequency[a]	17.28	28.59	$t(118) = -1.13$, $p = .26$
Imageability[b]	4.54	4.06	$t(118) = 1.95$, $p = .05$

a Printed word frequency per 100 million occurrences (Content et al., 1990).
b Rated by 51 subjects (mean age = 23.08, SD = 3.94) on a seven-point scale (1 = low imageability, 7 = high imageability).
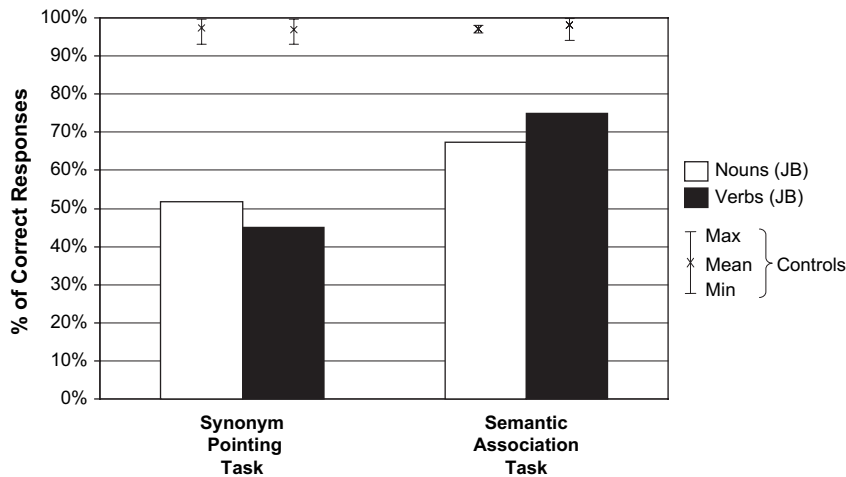
was composed of a cue written word (e.g., mouse) and two semantically related words (dog – cat). The patient was asked to point out the word that was the most closely related to the cue word (chance probability for a correct response = 1/2, 50%). Contrary to the synonym pointing task, in which the semantic relation between the cue word and the response word is stated explicitly in the task instructions and does not vary across trials ("best synonym"), the relation between the cue word and the response word in this task has to be discovered by the patient and differs across trials. The noun and verb items were presented within an ABBA design.[2]

5.3.2. Control sample

The control sample included 6 subjects (mean age = 73, mean number of years of education = 9).

5.3.3. Results

JB scored 67% (35/52) and 75% (39/52) for nouns and verbs, and the controls 97% (50.5/52, SD = .55) and 98% (51.2/52, SD = 1.17), on average (Fig. 3), respectively. The data analysis revealed that JB's performance was significantly impaired for both nouns [modified t-test: $t(5) = -26.10$, $p < .0001$] and verbs [modified t-test: $t(5) = -9.63$, $p < .0001$]. However, the test on the standardized difference between nouns and verbs revealed that her performance was significantly less impaired for verbs than nouns [RSDT: $t(5) = 9.06$, $p < .001$]. Moreover, although JB's performance was very poor, a non-parametric binomial test showed that it was significantly above the chance level for both verbs ($p = .001$) and nouns ($p < .02$).

5.4. Verb naming from videotaped actions

5.4.1. Material and procedure

A subset of 40 actions from the photograph naming task described above were selected. The selection criterion was that the actions were easily reproducible in a laboratory (e.g., actions performed by an animal were excluded). Videotapes of the corresponding actions were prepared, so that the visual appearance of the action resembles as closely as possible the way it was depicted on the photograph. Thus, with the exception of movement and duration, the videotapes contained no additional information about the action in comparison to the static pictures. No situational (e.g., place) or contextual (what comes before or next) information or sound was present in the videos. JB's performance in naming videotaped actions was compared to her performance in naming the corresponding verbs and matched nouns from the photograph naming task administered in May 2004, that is, 2 weeks after the videotaped naming task. In that way, any improvement in naming actions from videotapes compared to actions depicted in photographs could not be ascribed to a facilitation due to the repeated testing of the same items.

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[2] We attempted to present JB with the picture version of the semantic association task as well. Unfortunately, she refused to perform the task in this version and told us that she could not understand what she had to do with the pictures. It is worth noting that Bak and Hodges (2003) reported that, for normal controls, the picture version of both the PPT and the KDT tests was slightly but significantly more difficult than the word version.

Fig. 3 – JB's and controls' percentage of correct responses for nouns and verbs in two verbal comprehension tasks.

5.4.2. Control sample

Five control subjects (mean age = 68.8, mean number of years of education = 9) performed both the videotaped action naming task and the photograph naming task with the corresponding verbs and matched nouns.

5.4.3. Results

JB correctly named 50% (20/40) of actions from videotapes whereas she only named 25% (10/40) of the same actions presented as photographs; she correctly named 63% (25/40) of the matched nouns (see Fig. 4). In comparison with the controls, whose mean scores were 98% (39.2/40, SD = .84) for videotaped actions, 97% (38.8/40, SD = .45) for photograph actions, and 99.5% (39.8/40, SD = .45) for the matched nouns, JB's naming was significantly impaired in the three conditions [modified t-tests, videotaped actions: t (4) = −20.87, $p < .0001$; photograph actions: t (4) = −58.42, $p < .00001$; matched nouns: t (4) = −30.02, $p < .00001$]. However, in comparison with the controls' scores, JB's verb naming performance in the videotape condition was significantly better than her performance in the photograph condition [RSDT: t (4) = 13.04, $p < .001$]. Moreover, although her raw score for verbs in the videotape

condition was still lower than her raw score for the matched nouns, when compared to the controls' differences, JB's naming performance for verbs in the videotape condition appeared significantly *less* impaired than her naming performance for the matched nouns [RSDT: t (4) = 4.72, $p < .01$]. Thus, the presentation of actions in videotapes led to a significant improvement of JB's verb naming so much that the seemingly disproportionate verb deficit observed with the photographs of actions was not observed any more.

5.4.4. Discussion

The results presented in this section are consistent with the view that the nature of the stimuli used to assess verb processing, that is, static pictures of actions, was responsible for JB's verb disproportionate deficit in the naming and the word–picture verification task. In connected speech and in two word comprehension tasks not involving picture stimuli, no evidence was found for a verb disproportionate deficit in JB's performance.

Admittedly, the findings from the connected speech analyses could be due to the relatively high frequency of verbs used in everyday conversations, which could make them less
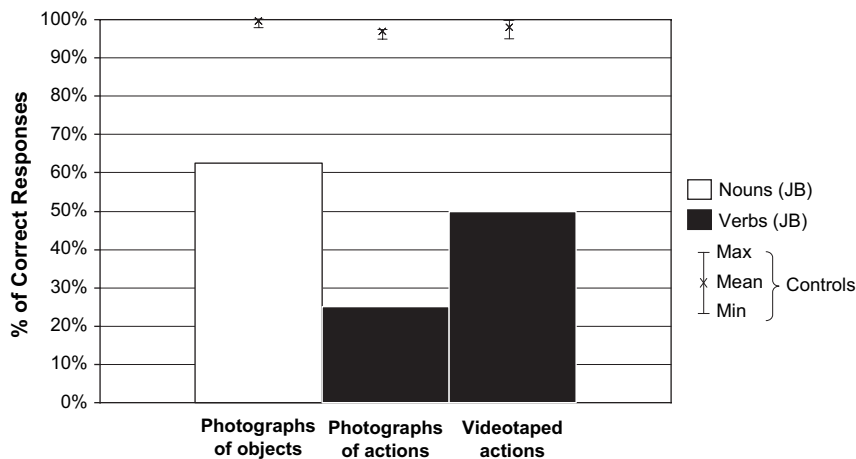

Fig. 4 – JB's and controls' percentage of correct responses in naming photographs of objects, photographs of actions, and videotaped actions.

vulnerable to lexical–semantic damage than less frequently used nouns. Still, the absence of a verb disproportionate deficit in the synonym pointing and the semantic association tasks was very unlikely due to the same bias: in both verbal comprehension tasks, nouns and verbs were closely matched for frequency of use. Furthermore, it is unlikely that the absence of a verb disproportionate deficit in both verbal comprehension tasks was due to these tasks either lacking sensitivity to JB's lexical–semantic deficit (ceiling effect) or being too difficult and hence obscuring any possible grammatical class effect (floor effect). First of all, let us remind that JB's performance in both verbal comprehension tasks was neither at ceiling nor at floor; her performance was relatively poor but significantly higher than the chance level. Second, both verbal comprehension tasks, like the word–picture verification task, require fine semantic discrimination between closely related words. Third, although the stimulus words were, on average, of lower frequency in the synonym pointing task than in the word–picture verification task, which could have made the synonym task more difficult and hence could have obscured any grammatical class effect, the stimulus words used in the semantic association task were of comparable frequency to those used in the word–picture verification task (see Table 6). Still, JB was significantly *less* impaired for verbs than nouns in the association task.

Finally, the results from the videotaped action naming task provided direct evidence for the role of static depictions of action in JB's performance. In this task, the patient's performance significantly improved in comparison to her performance with static pictures of actions and even if her raw scores for verbs failed to reach her scores for nouns, when compared with the distribution of differences between verbs and nouns in the control sample, her deficit in naming verbs from videotaped actions turned out to be significantly less severe than her deficit in naming nouns. Yet the task was the same as the one that revealed a verb disproportionate deficit (namely, spoken naming) and involved, in addition, the same target words.

6. General discussion

We have reported the case of an fv-FTD patient who was more impaired in naming and comprehending verbs than nouns in a picture naming task and a word–picture verification task. In the neuropsychological literature of the last two decades, there have been numerous reports of such grammatical class specific deficits in the performance of brain-damaged patients (for review, see Shapiro and Caramazza, 2003) and, as Druks (2002) noted, it is very likely that such deficits "occur in different patients for different reasons". In the case JB, we were able to show that the verb disproportionate deficit was not caused by a number of lexical and semantic characteristics that may make verbs more difficult to name or understand than nouns, such as word frequency, concept familiarity, and degree of semantic relatedness between target and foils in a comprehension task. We showed that, contrary to the account put forward by Rhee et al. (2001) and Silveri et al. (2003) for the verb disproportionate deficit found in their groups of FTD patients, JB's verb deficit was not caused by a disproportionate difficulty in recovering verb lexical–semantic information in comparison to noun information, since the verb deficit disappeared in tasks involving exclusively verbal stimuli. We then showed that JB in fact had more difficulties in naming verbs than nouns because verbs were elicited from static pictures of actions. When videotaped actions were used instead of static depictions, JB did not encounter significantly more difficulties in naming verbs than nouns – in fact, she even appeared to be less impaired in naming verbs than nouns, when the difference between her scores on videotaped verbs and nouns was compared with the distribution of differences between verbs and nouns in the control sample.

Why did JB encounter more difficulties with static depictions of actions than with pictures of objects? In Section 1, we suggested that recognizing actions from static depictions (photographs or drawings) is more resource demanding than recognizing objects from the same kind of depictions because not only are the stimuli and the task less familiar in everyday life but it also requires recovering information that is lacking in static scenes (i.e., the temporal and movement features of the action) and yet crucial for the recognition of the action. Hence, a patient suffering from executive resource limitations should experience more difficulties with this kind of stimuli, at least in certain conditions, i.e., when the concurrent task (e.g., word–picture matching or naming) also imposes high demands of executive resources. The pattern of JB's performance across the various tasks provides some evidence in support of this account.

To begin with, it is worth emphasizing that JB's difficulties with static depictions of actions very unlikely arose at the visuoperceptual level of processing. There was no evidence of visuoperceptual processing difficulties in JB. First, her naming performance improved with the videotaped actions, which are more complex visual stimuli than photographs of actions. Second, she performed within the normal range at

Table 6 – Comparison of the mean log frequency of the stimulus words in the two verbal comprehension tasks and the word–picture verification task			
	Synonym pointing task	Word–picture verification task	t-Tests
Nouns	6.49	7.16	t (112) = −2.34, p < .05
Verbs	6.47	7.46	t (112) = −3.20, p < .005
Total	6.48	7.31	t (226) = −3.94, p < .001
	Semantic association task	Word–picture verification task	t-Tests
Nouns	7.04	7.16	t (101) = −.42, p = .67
Verbs	7.94	7.46	t (99) = 1.49, p = .14
Total	7.48	7.31	t (202) = .80, p = .42

Note. Frequency was taken from Content et al. (1990). Frequency values were missing for 3 nouns and 5 verbs in the semantic association task.

the picture naming task and the multiple-choice word–picture matching task from LEXIS (see Section 2), which included only depiction of objects, as well as at the multiple-choice word–photograph matching task, which included both objects and actions – in fact, an array of four pictures of objects or of actions. Thus, in some conditions at least, JB was able to "recognize" pictures of both objects and actions. On the other hand, JB's contrasting pattern of performance in the two word-to-picture matching tasks, the verification and the multiple-choice task, clearly suggests that her ability to recognize pictures of actions varies as a function of the demands otherwise imposed by the task. Although both these tasks included exactly the same stimulus words and pictures, JB's response accuracy dramatically declined, for both nouns and verbs, in the verification task in comparison with the multiple-choice task, which suggests that the first task imposed more cognitive demands than the latter. The decline of JB's accuracy in the picture verification task, especially for the pictures of actions – which resulted in a disproportionate "verb deficit" – further suggests that recognizing (static) pictures of actions engages more resource demanding processes than recognizing pictures of objects.[3]

To what extent differences in processing difficulty between static depictions of actions and objects might account for the disproportionate verb deficits previously reported in the literature is difficult to know. To the best of our knowledge, among the studies with aphasic patients, very few have attempted to control this factor. Among them, Berndt et al. (1997) showed that a group of 11 aphasic patients presenting with a disproportionate naming deficit for verbs when elicited from static pictures demonstrated a parallel pattern when verbs were elicited from videotaped actions. In a single case study of an aphasic subject LC (d'Honincthun and Pillon, 2004), we also showed that the patient presented a comparable disproportionate verb deficit whether he named actions from photographs or videotapes.[4] However, in a number of case reports of aphasic patients such control was unnecessary, either because the verb disproportionate deficit showed up also in tasks not involving picture stimuli (e.g., Breedin and Martin, 1996; Marshall et al., 1996; Zingeser and Berndt, 1990) or because it was present in spoken (e.g., Caramazza and Hillis, 1991) or written (e.g., Rapp and Caramazza, 1998, 2002) picture naming only. This holds for only one study with FTD patients, who also showed a modality-specific verb naming impairment

(Hillis et al., 2002). In all the other previously reported DAT or FTD patients presenting a verb disproportionate deficit, the results were based only on tasks including static pictures of actions and objects, where either both spoken and written naming was more impaired for verbs than nouns (Robinson et al., 1996; White-Devine et al., 1996) or only one output modality was tested (Bak et al., 2001; Cappa et al., 1998; Rhee et al., 2001; Silveri et al., 2003). Thus, in light of the findings of the present case study, all these reports of verb disproportionate deficits must be considered with caution; their data on the putative noun/verb dissociation may not be appropriate for drawing inferences about the functional and neural organisation of lexical and semantic knowledge.

It is worth adding that there is evidence in the dementia literature which suggests that the pattern found in our patient was probably not idiosyncratic. Thus, Bak and Hodges (2003) recently reported the performance of a group of 10 fv-FTD patients and a group of 14 patients with SD on a semantic association task including triplets of verbs or (static) action pictures (KDT) and triplets of nouns or object pictures (PPT). The patients with fv-FTD were significantly more impaired on the KDT, but only for the picture version of the task, whereas the patients with SD were more impaired on the PPT for the word version only. This pattern is consistent with the finding of the present study suggesting that fv-FTD patients may encounter specific difficulties in processing actions from static pictures.

Let us make clear, however, that we are not arguing that verb disproportionate deficits in dementia patients could not originate from a lexical, semantic, or syntactic impairment affecting verbs more than nouns. The two reports of DAT patients with verb *preservation* (Parris and Weekes, 2001; Robinson et al., 1999) indeed suggest that verb and noun processing may dissociate in dementia. Instead, we would like to point out that if we want to use data from dementia populations to inform theories about the representation of lexical–semantic or syntactic knowledge in mind and brain, we should carefully try to disentangle in the patient's pattern of performance, the relative contribution of lexico-semantic or syntactic deficits and of executive resource limitation – which, not incidentally, will also advance our understanding of the executive components involved in the tasks commonly used to probe lexical, semantic, and syntactic knowledge. Such endeavour probably is crucial in the cases of dementia, where major cognitive resource limitations may typically be expected. However, given the reduction of cognitive efficiency produced by any brain lesion, the need of considering the potential effects of using rather unusual stimuli for assessing verb processing should be kept in mind, whatever the underlying aetiology.

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[3] It was far beyond the scope of this study to specify the nature of the resource pool that contributes to the recognition of static depictions of actions and of which limitation may interfere with the ability to recover and manipulate lexical–semantic information. In particular, this study did not address the question of whether the limited-capacity resources recruited for the recognition of static depictions of actions are *specific* executive resources engaged in recovering semantic knowledge (Wagner et al., 2001) or more general executive resources, like attention or working memory, engaged in any kind of controlled processes. Whether executive resource limitation would affect action recognition in static pictures only in the condition of an associated deficit in lexical–semantic processing or even when lexical–semantic processing is spared is a question that also awaits further empirical studies.

[4] LC was presented the same photograph and videotaped stimuli as those presented to JB.

REFERENCES

Baddeley AD, Emslie H, and Nimmo-Smith I. *Doors and People: A Test of Visual and Verbal Recall and Recognition*. Suffolk: Thames Valley Test Company, 1994.

Bak TH and Hodges JR. Kissing and Dancing – a test to distinguish the lexical and conceptual contributions to noun/verb and action/object dissociation. Preliminary results in patients with frontotemporal dementia. *Journal of Neurolinguistics*, 16: 169–181, 2003.

Bak TH, O'Donovan DG, Xuereb JH, Boniface S, and Hodges JR. Selective impairment of verb processing associated with pathological changes in Brodmann areas 44 and 45 in the motor neurone disease–dementia–aphasia syndrome. *Brain*, 124: 103–120, 2001.

Berndt R, Mitchum C, Haendiges A, and Sandson J. Verb retrieval in aphasia: 1. Characterizing single word impairment. *Brain and Language*, 56: 68–106, 1997.

Bird H, Lambon Ralph MA, Patterson K, and Hodges JR. The rise and fall of frequency and imageability: noun and verb production in semantic dementia. *Brain and Language*, 73: 17–49, 2000.

Breedin SD and Martin RC. Pattern of verb impairment in aphasia: an analysis of four cases. *Cognitive Neuropsychology*, 13: 51–91, 1996.

Breese EL and Hillis AE. Auditory comprehension: is multiple choice really good enough? *Brain and Language*, 89: 3–8, 2004.

Cappa SF, Binetti G, Pezzini A, Padovani A, Rozzini L, and Trabucchi M. Object and action naming in Alzheimer's disease and frontotemporal dementia. *American Academy of Neurology*, 50: 351–355, 1998.

Caramazza A and Hillis AE. Lexical organization of nouns and verbs in the brain. *Nature*, 349: 788–790, 1991.

Content A, Mousty P, and Radeau M. Brulex. Une base de données lexicales informatisée pour le français écrit et parlé. *L'Année psychologique*, 90: 551–566, 1990.

Crawford JR and Garthwaite PH. Testing for suspected impairments and dissociations in single case studies in neuropsychology: evaluation of alternatives using Monte Carlo simulations and revised tests for dissociations. *Neuropsychology*, 19: 318–331, 2005.

Crawford JR, Garthwaite PH, Azzalini A, Howell DC, and Laws KR. Testing for a deficit in single case studies: effects of departures from normality. *Neuropsychologia*, 44: 666–676, 2006.

Crawford JR and Howell DC. Comparing an individual's test score against norms derived from small samples. *The Clinicial Neuropsychologist*, 12: 482–486, 1998.

de Partz MP, Bilocq V, de Wilde V, Seron X, and Pillon A. *LEXIS. Tests pour le diagnostic des troubles lexicaux chez le patient aphasique*. Marseille: Solal, 2001.

de Renzi E and Vignolo L. The token test: a sensitive test to detect receptive disturbance in aphasics. *Brain*, 85: 665–678, 1962.

Druks J. Verbs and nouns – a review of the literature. *Journal of Neurolinguistics*, 15: 289–315, 2002.

d'Honincthun P and Pillon A. *A Deficit in Action Naming: Semantic or Grammatical Class Effect?* Modena, Italy: First Congress of the European Neuropsychological Societies, 2004.

Ellis HD and Lewis MB. Capgras delusion: a window on face recognition. *Trends in Cognitive Sciences*, 5: 149–155, 2001.

Fiez JA and Tranel D. Standardized stimuli and procedures for investigating the retrieval of lexical and conceptual knowledge for actions. *Memory and Cognition*, 25: 543–569, 1997.

Fung TD, Chertkow H, Murtha S, Whatmough C, Peloquin L, Whitehead V, and Templeman FD. The spectrum of category effects in object and action knowledge in dementia of the Alzheimer's type. *Neuropsychology*, 15: 371–379, 2001.

Hillis AE, Tuffiash E, and Caramazza A. Modality-specific deterioration in naming verbs in nonfluent primary progressive aphasia. *Journal of Cognitive Neuroscience*, 14: 1099–1108, 2002.

Hodges JR, Salmon DP, and Butters N. Semantic memory impairment in Alzheimer's disease: failure of access or degraded knowledge? *Neuropsychologia*, 30: 301–314, 1992.

Howard D and Patterson K. *The Pyramids and Palm Trees Test: A Test of Semantic Access from Words and Pictures*. Bury St. Edmunds, UK: Thames Valley Test Company, 1992.

Laws KR, Gale TM, Leeson VC, and Crawford JR. When is category specific in Alzheimer's disease? *Cortex*, 41: 452–463, 2005.

Marshall J, Chiat S, Robson J, and Pring T. Verb retrieval and sentence production in aphasia. *Brain and Language*, 63: 159–183, 1996.

Mayer JF and Murray LL. Functional measures of naming in aphasia: word retrieval in confrontation naming versus connected speech. *Aphasiology*, 17: 481–497, 2003.

New B, Pallier C, Brysbaert M, and Ferrand L. Lexique 2: a new French lexical database. *Behavior Research Methods, Instruments, and Computers*, 36: 516–524, 2004.

New B, Pallier C and Ferrand L. Documentation officielle de Lexique 3. <http://www.lexique.org/documentation.php>, 2005.

Norman DA and Shallice T. Attention to action. Willed and automatic control of behaviour. In Davidson RJ, Schwartz GE, and Shapiro D (Eds), *Consciousness and Self-regulation. Advances in Research and Theory*, vol. 4. New York: Plenum press, 1986: 1–18.

Parris B and Weekes B. Action naming in dementia. *Neurocase*, 7: 459–471, 2001.

Rapp B and Caramazza A. A case of selective difficulty in writing verbs. *Neurocase*, 4: 127–140, 1998.

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

Rey A. *Test de copie d'une figure complexe: Manuel*. Paris: Editions du Centre de Psychologie Appliquée, 1959.

Rhee J, Antiquena P, and Grossman M. Verb comprehension in frontotemporal degeneration: the role of grammatical, semantic and executive components. *Neurocase*, 7: 173–184, 2001.

Robinson K, Grossman M, White-Devine T, and D'Esposito M. Category-specific difficulty naming with verbs in Alzheimer's disease. *Neurology*, 47: 178–182, 1996.

Robinson G, Rossor M, and Cipolotti L. Selective sparing of verb naming in a case of severe Alzheimer's disease. *Cortex*, 35: 443–450, 1999.

Segalowitz SJ and Lane KC. Lexical access of function versus content words. *Brain and Language*, 75: 376–389, 2000.

Shallice T. *From Neuropsychology to Mental Structure*. Cambridge, UK: Cambridge University Press, 1988.

Shapiro K and Caramazza A. The representation of grammatical categories in the brain. *Trends in Cognitive Sciences*, 7: 201–206, 2003.

Silveri MC, Salvigni BL, Cappa A, Della Vedova C, and Puopolo M. Impairment of verb processing in frontal variant-frontotemporal dementia: a dysexecutive symptom. *Dementia and Geriatric Cognitive Disorders*, 16: 296–300, 2003.

Snowden JS, Griffiths HL, and Neary D. Semantic–episodic memory interactions in semantic dementia: implications for

retrograde memory function. *Cognitive Neuropsychology*, 13: 1101–1137, 1996.

Van der Linden M, Coyette F, Wyns C, Calicis F, and Le Groupe «MÉMOIRE» DU GRECO. Epreuve de rappel libre/rappel indicé à 16 items (RL/RI-16). In Van der Linden M (Ed), *L'évaluation des troubles de la mémoire. Présentation de quatre tests de mémoire épisodique (avec leur étalonnage)*. Marseille: Solal, 2004: 25–47.

Wagner AD, Pare-Blagoev EJ, Clark J, and Poldrack RA. Recovering meaning: left prefrontal cortex guides controlled semantic retrieval. *Neuron*, 31: 329–338, 2001.

Wechsler DA. *Echelle d'intelligence de Wechsler pour adultes forme révisée WAIS-R*. Paris: Editions du Centre de Psychologie appliquée, 1989.

White-Devine T, Grossman M, Robinson K, Onishi K, Biassou N, and d'esposito M. Verb confrontation naming and word–picture matching in Alzheimer's disease. *Neuropsychology*, 10: 495–503, 1996.

Zingeser LB and Berndt RS. Retrieval of nouns and verbs in agrammatism and anomia. *Brain and Language*, 39: 14–32, 1990.