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DEGRADED SEMANTIC KNOWLEDGE AND ACCURATE OBJECT USE

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Abstract

In the present paper we report the performance on object use and on semantic tasks of two patients, D.L. with probable semantic dementia, and A.M. with an atypical onset of dementia of Alzheimer, assessed twice two years apart. In particular, we investigated whether the patients' ability to use objects degraded as a function of their semantic knowledge about those objects. Results from the two assessments in 2002 and in 2004 confirmed that both patients had a selective loss of the lexical-semantic knowledge, despite a relative preservation of the other cognitive abilities including object use. This pattern of results suggests that semantic knowledge is not necessarily involved in the correct use of objects.

Key words: apraxia, semantic dementia, object use, parietal cortex

Introduction

In 1975 Elizabeth Warrington described three patients with progressive anomia and impaired word comprehension. This syndrome has been successively considered as the temporal variant of the frontotemporal dementia, and as the fluent form of primary progressive aphasia (Luzzatti, 1999; Hodges et al., 1992; Snowden et al., 1989). Since it impacts primarily on the semantic memory of patients, the term "semantic dementia" (SD) has been proposed for it (Hodges et al., 1992; Snowden et al., 1989). Others called the same neuropsychological pattern *slowly progressive aphasia* as the conceptual loss is usually accompanied by a lexical deficit (see Poeck and Luzzatti, 1988). Whereas SD patients' naming and spontaneous speech are interspersed with anomias and semantic paraphasias, perceptual skills, non-verbal intelligence, syntactic skills, repetition and day-to-day memory may be relatively spared at least at an earlier stage of the disease (Bozeat et al., 2000; Lambon Ralph and Howard, 2000). SD is generally associated with circumscribed temporal lobe atrophy, affecting the temporal pole, the antero-medial and infero-lateral temporal lobe, bilaterally but asymmetrically. In addition, the ventromedial frontal cortex and the amygdaloid complex have been found affected too (Mummery et al., 1999, 2000). As shown in post-mortem examinations, in some instances the symptoms of progressive aphasia and semantic-lexical impairment may also reflect an atypical focal dementia of Alzheimer type (see Galton et al., 2000; Greene et al., 1996).

Based on the behaviour of patients with impaired semantics, conceptual knowledge has been suggested to be modality-specific, as it was found to be affected either in its verbal (Lauro-Grotto et al., 1997; McCarthy and Warrington, 1988; Coughlan and Warrington, 1981) or in its visual component (Warrington and McCarthy, 1994). These findings have been taken as evidence that the semantic system is indeed multimodal (Shallice, 1988). The fact, however, that patients with degraded knowledge for verbal and non-verbal stimuli have also been reported (Hodges et al., 1992; Snowden et al., 1989; Bozeat et al., 2000), supported the opposite view that the semantic system is amodal (Caramazza et al., 1990; Riddoch et al., 1988).

Interestingly, at least two SD patients have been reported with spared object use in the presence of semantic memory impairments. For instance, patients R.M. and D.M., described by Lauro-Grotto et al. (1997) and Buxbaum et al. (1997) respectively, were still able to use objects in everyday activities despite having a deficit in object naming and identification. Hodges et al. (2000) too described patients who, in some instances, were better at using objects than would have been predicted based on their semantic knowledge about those objects.

In sharp contrast with the behavioural pattern shown by patients with probable SD is that characterizing patients with ideational apraxia (IA), defined as a selective deficit of object use. It has been suggested that this deficit is often caused by lesions of the left hemisphere (e.g., De Renzi and Lucchelli, 1988), and in particular of the left inferior parietal lobe (Rumiati et al., 2004; see Johnson-Frey, 2004 for a review). IA patients have been described with a deficit in object use but with no semantic impairments (see Rosci et al., 2003).

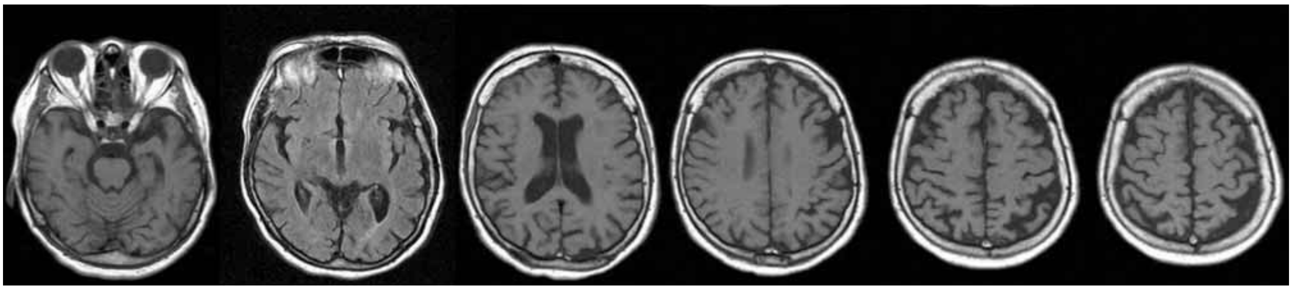

Fig. 1 – *Selected images from the MR scan performed on patient A.M. in March 2005. The diffused amplitude of liquoral spaces is evident in the ventricular and subaracnoidal spaces and in the fronto-temporo-parietal regions bilaterally, more pronounced in the left hemisphere. This neuroradiological finding fits well with a diagnosis of a dementia of Alzeheimer's type.*

Moreover, a few patients have been reported with a completely preserved performance on tests tapping semantic knowledge about the same objects they failed to use (patients D.R. and F.G. in Rumiati et al., 2001; but see also patient H.B. in Buxbaum et al., 1997). In general, several patients with spared semantic knowledge in the presence of object use impairment have been described in literature (Ochipa et al., 1989; case 3 in Hodges et al., 1999; Buxbaum et al., 2000) Double dissociations between the ability to perform tasks tapping semantic information about objects and the movements necessary to use them appropriately indicate that these two abilities might be independent and have different cerebral correlates (see Rumiati et al., 2004).

According to some authors (Coccia et al., 2004; Bozeat et al., 2002a, 2002b; Hodges et al., 2000), as SD progresses, patients become also apraxic. Hodges et al. (2000), and Bozeat et al. (2000) reported SD patients who were still able to use highly familiar but not less common items, and therefore concluded that the object familiarity is the best predictor of proper use. Because of the strong correlation between the performance on object use and the preservation of the semantic knowledge about objects, Hodges et al. (2000) argued that in SD patients the spared praxic skills seem to rely strictly upon object-specific conceptual knowledge, in addition to the mechanical problem solving abilities and visual affordances. Furthermore, object use performance seems to be strongly influenced by the context in which the objects are presented. Indeed Bozeat et al. (2002b) observed that patients' performance improved significantly when they were assessed at home, using objects that belonged to them, as opposed to when they were tested in the laboratory using objects perceptually dissimilar to those of their own.

The theoretical inferences cannot be conclusive for the patients who showed a dissociation were tested using different stimuli in the tasks assessing object knowledge and object use (e.g., Buxbaum et al., 1997; Lauro-Grotto et al., 1997). Therefore the dissociations reported could have been due to items presenting different degrees of difficulty in either one or the other task.

Here we report a two-year longitudinal study in which we assessed the ability to use objects of two patients, D.L. with probable semantic dementia and A.M. with an atypical onset of a dementia of Alzheimer type, as well as their lexical-semantic knowledge concerning the same objects. The aim of the study was to verify whether semantic information is necessary to correctly use objects. Evidence that the integrity of the semantic knowledge is not sufficient to support tool use comes from the observation of patients with IA (Rumiati et al., 2001; Buxbaum et al., 2000; Hodges et al., 1999; Ochipa et al., 1989).

Method

Participants

Patients

A.M. is a right-handed woman born in 1928, with five years of education, who, before retirement, worked as a farm labourer. On March 2002 she underwent a neuropsychological assessment because of word finding impairment and memory problems. Two months earlier, a single photon emission computed tomography (SPECT) was performed revealing a concentration deficit of the tracer in the left temporal lobe. A more recent nuclear magnetic resonance (NMR) (March 2005) scan revealed a diffused cerebral atrophy (see Figure 1), although she was described by her family as still able to carry out a relatively normal life, and to perform everyday activities such as cooking and keeping her flat clean, without obvious difficulties.

D.L. is a right-handed man born in 1933, with five years of education, who, before retirement, worked as a baker and lorry-driver. In October 2000 he was referred for a neuropsychological evaluation for a name retrieval problem, affecting proper names (people and streets) as well as names of animals and objects of common use. A NMR scan in September 2000 revealed bilateral temporal lobe atrophy, greater in the left temporal pole and Sylvian areas (see Figures 2 and 3). Notwithstanding his severe semantic memory

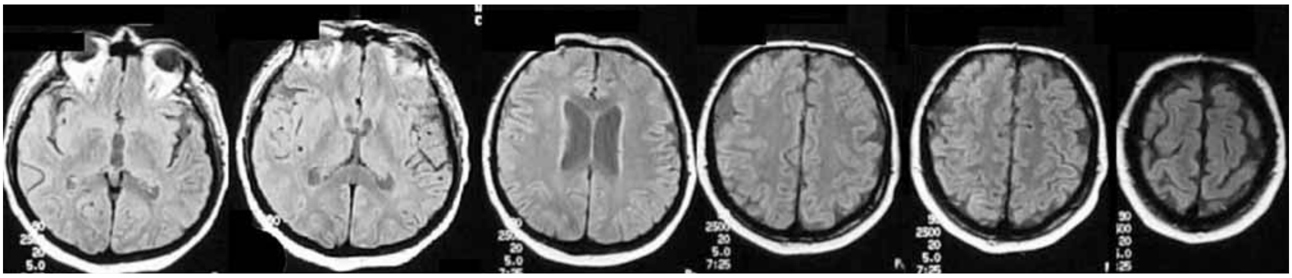

Fig. 2 – *Selected images from the MR scan performed on patient D.L. in September 2000.*

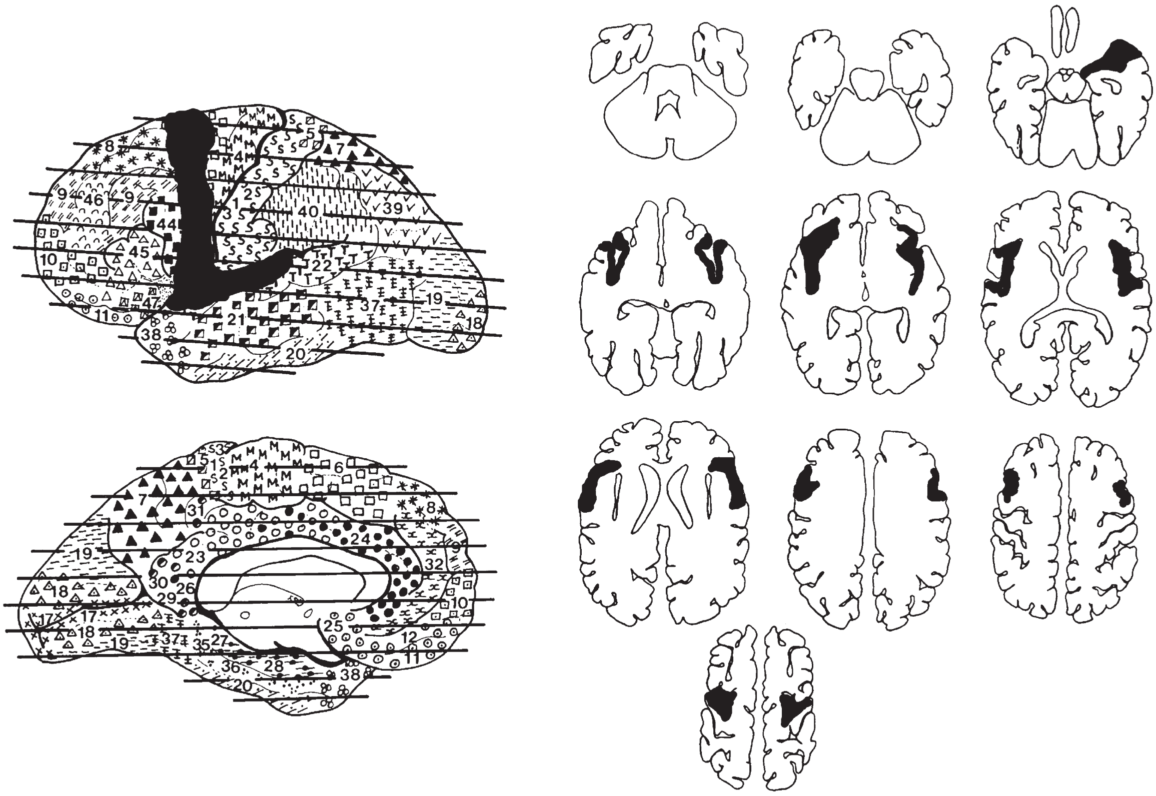

Fig. 3 – *Reconstruction of the areas most affected by cortical atrophy in patient D.L. The atrophy involves fronto-temporal regions, bilaterally.*

deficit, D.L. has managed to conduct a normal life, maintaining the driving licence. In the follow-up evaluation of 2004, besides his severe word finding difficulties, D.L. appeared also to have become short-tempered, easily irritable and edgy. Because of his attitude and lack of motivation, some of the tests could not be administered and he refused to undergo a follow-up MR scan in 2004.

Patients were tested first in April-July 2002 and subsequently in May-August 2004. The testing was carried out at the hospital as well as at the patients' home in three-four different sessions that lasted about two hours each.

Controls

The performance of patients in Experiments 2-5 of the study was compared with that of twenty individuals (10 males and 10 females) matched for age (mean = 61.1 years, SD = 9.45 years) and education (mean = 9.7 years, SD = 3.3 years).

General Neuropsychological Assessment

Results of A.M. and D.L. on the neuropsychological assessment are reported in Table I.

Orientation in Time and Space

A.M. was well-oriented in space and time in 2002, while in 2004 she was slightly disoriented in time (she was unsure about the current year but showed no problem in reporting the season as well as the month), but not in space. D.L. was well-oriented in time and space in both evaluations.

TABLE I

*Patients' scores on the general neuropsychological assessment**

			A.M.		D.L.		
			2002	2004	2002	2004	Cut-off
	MMSE		**15/30**		**21/30**		
Intelligence	Raven's CMT	Total score	**17.4 a.s.**	19.2 a.s.	31	32.5 a.s.	18.96
Language	AAT	Token test (PR)	**68**	**77**	91	n.a.	
		Repetition (PR)	**74**	**64**	94	46/50	
		Writing (PR)	84	**71**	75	n.a.	
		Naming (PR)	**61**	**56**	**60**	n.a.	
		Comprehension (PR)	81	**39**	85	Reading words: 9/10	
Linguistic fluencies		For letters	20.6	**14.4**	n.a.	**0**	17.35
		For semantic categories	11.5	7.25		**0**	7.25
Visual processing	VOSP	Screening test	18	17	18	20	15
		Incomplete letters	**12**	**10**	17	n.a.	16
		Object decision	16	**7**	16	15	14
Memory	Short-term	Corsi test	**2.25 a.s.**	4.25 a.s.	5	5	
		Digit span forward	5.5 a.s.	4.5 a.s.	4	5	
		Backward	3	3	n.a.	3	
	Long-term	Rey-words immediate recall	**18**	**16 a.s.**	n.a.	n.a.	28.53
		Delayed recall	**3.4**	**0**	n.a.	n.a.	4.69
		Recognition corr.	**12/46**	**17/46**	n.a.	n.a.	
		False recognitions	**23**	**27**	n.a.	n.a.	
		Word recognition memory	n.a.	**28/50**	**28/50**	**26/50**	
		Face recognition memory	**16/25**	**16/25**	**12/25**	n.a.	

Note. The bold character indicates pathological scores; a.s. = adjusted score; PR = percentile rank; n.a. = test not administered.

Language

Linguistic abilities were affected in both patients on the Aachener Aphasie Test (AAT) (Luzzatti et al., 1996); in particular, their naming ability was severely impaired. In 2002, repetition, comprehension, reading, and writing skills were well-preserved in patient D.L. In 2002 A.M. showed a deficit in repetition particularly of long sentences, suggesting a deficit in maintaining verbal information for short time periods. She was impaired also in the Token subtest of the AAT, revealing a deficit in comprehension of simple orders. In 2004 only a short version of the AAT could be administered to D.L., whereas A.M. resulted impaired also in writing and in sentence comprehension, as compared with the previous evaluation.

Memory

Spatial (Corsi test; De Renzi and Nichelli, 1975) and verbal short-term memory (digit span, Wechsler Adult Intelligence Scale – WAIS), and working memory (backwards digit span, WAIS) were in the normal range for both patients, in the 2002 as well as in the 2004 evaluation. However, they were both found having severe anterograde memory deficits, as suggested by their performance on a recognition memory test which employs words as well as faces (Warrington, 1996), and as indicated by the results on the Auditory Verbal Learning test (Rey, 1964). During the clinical interview, both patients had no difficulty in reporting autobiographical data and information about their relatives. They were also accurate in describing their usual daily activities and recent personal events.

Non-Verbal Intelligence (Raven, 1984)

Non-verbal intelligence was stable across evaluations, within the normal range for D.L. and in the low average range for A.M.

Vision

In contrast to A.M., who performed below the cut-off on the Incomplete Letter test (visual object and space perception battery – VOSP; Warrington and James, 1991) in 2002 as well as in 2004, D.L.'s visual processing resulted well-preserved in both evaluations.

In the following sections, a brief description of the tests aimed at investigating the semantic memory and praxic abilities of the two patients is provided, followed by the results.

Semantic Memory

Picture Naming (Laiacona et al., 1993)

Patients were asked to name 80 line drawings presented in a random order. As in the original study (Laiacona et al., 1993), synonyms and other acceptable nouns were scored as correct responses. A.M.'s and D.L.'s performance on this task was severely impaired in both evaluations (see Table II), making semantic paraphasias and omissions.

TABLE II
Patients' performance on different tests assessing semantic memory

			A.M.		D.L.	
Semantic memory	2002	2004	2002	2004	Cut-off	
Laiacona et al. (1993)	Naming	**40/80 (50%)**	**30/80 (38%)**	**32/80 (40%)**	**18/80 (23%)**	61/80
	Comprehension between-cat	79/80 (98%)	75/80 (93%)	79/80 (98%)	n.a	93%
	Comprehension within-cat	**73/80 (91%)**	**71/80 (89%)**	**65/80 (81%)**	**40/80 (50%)**	93%
Pyramids and Palm Trees Test	Words	**41/52 (79%)**	**38/52 (73%)**	**40/52 (77%)**	n.a	48
	Pictures	**35/52 (67%)**	**39/52 (75%)**	**38/52 (73%)**	**26/52 (50%)**	48
SISSA Object Semantics:						
Manipulation knowledge	Words	**8/17 (47%)**	**6/17 (35%)**	**9/17 (53%)**	n.a	
	Pictures	**10/17 (59%)**	**7/17 (41%)**	**9/17 (53%)**	n.a	
Function knowledge	Words	**15/17 (88%)**	**8/17 (47%)**	**10/17 (59%)**	n.a	
	Pictures	**13/17 (76%)**	**10/17 (59%)**	**11/17 (65%)**	n.a	

Note. The bold character indicates pathological scores.

Following Laiacona et al. (1993), patients' scores were submitted to a logistic regression including a categorical variable (category: living *vs*. non-living items), and continuous variables (familiarity, word frequency and prototypicality) in order to partial out the effect of possible confounds. A.M. did not show a significant effect of category neither in 2002 nor in 2004 ($p > .05$ for both comparisons on a Chi-square test, $df = 1$), even when the effect of psycholinguistic variables was partialled out. However, her performance was affected by word frequency in 2002 (Chi-square = 4.8, $df = 1$, $p < .05$) as well as in 2004 (Chi-square = 8.54, $df = 1$, $p < .01$).

D.L. showed, both in 2002 and in 2004, a significant effect of category, in that he named nonliving better than living items (in 2002: Chi-square = 5.99, $df = 1$, $p < .05$; in 2004: Chi-square = 7.4, $df = 1$, $p < .01$), as well as a significant effect of word frequency (in 2002: Chi-square = 10.29, $df = 1$, $p = .001$; in 2004: Chi-square = 18.88 $df = 1$, $p < .001$). In 2004, his naming performance was significantly predicted also by the familiarity of the stimulus (Chi-square = 4.22, $df = 1$, $p < .05$).

Patients' accuracy in naming was consistent over time (D.L.: consistency coefficient = .40, Chi-square = 14.9, $p < .001$; A.M.: consistency coefficient = .49, Chi-square = 25.2, $p < .001$). As compared to 2002, D.L.'s naming performance in 2004 worsened significantly, but not that of A.M. (McNemar test, $p < .05$, and $p > .05$, 1 tailed, respectively). Results are reported in Table II.

Word to Picture Matching (Laiacona et al., 1993)

Patients were asked to point, among five pictures (one correct and four foils), to the one named by the examiner. This task was presented in two different conditions: within-category, with foils belonging to the same category of the target, and between-categories, with foils belonging to categories different from that of the target. Patients' scores and cut-offs are reported in Table II. Both patients performed below the normal range in 2002 as well as in 2004 in the within-category, but not in the between-categories condition. Compared with that in 2002, A.M.'s performance worsened in 2004 in the within-category condition (McNemar test, $p < .05$) but not in the between-categories condition ($p > .05$). D.L. scored worse in 2004 than in 2002 in the within-category condition ($p < .05$). In 2004 he was not administered with the between-categories condition (see Table II).

Pyramids and Palm Trees Test
(Howard and Patterson, 1992)

In this test, patients were required to indicate, between two foils, the one semantically related to the target (e.g., pyramid: palm tree or pine?). Two versions of the test were administered, one using written words and the other using pictures as stimuli. A.M. and D.L. scored below the normal cut-off in performing either versions in 2002 as well as in 2004, but only D.L.'s performance on the second evaluation was significantly lower than that on the first evaluation (McNemar test, $p < .05$) performing at chance level when pictures were used (the verbal version was administered only in 2002). Results are reported in Table II.

SISSA Object Semantics (SOS)

This test was created in order to investigate the patients' integrity of the knowledge about the functions and manner of manipulation of objects. Three line drawings depicting objects were shown

TABLE III

P-values associated to a Wilcoxon signed rank test, comparing A.M.'s and D.L.'s performance on the verbal and the visual version of the tasks

Experiment		Patient A.M. 2002	Patient A.M. 2004	Patient D.L. 2002	Patient D.L. 2004
Exp. 3 (General semantics)		> .01	> .01	> .01	> .01
Exp. 5 (Manipulation knowledge)		> .01	> .01	> .01	> .01
SISSA Object Semantics					
	Function	> .01	> .01	> .01	n.a.
	Manipulation	> .01	> .01	> .01	n.a.

Note. n.a. = not administered.

on a sheet to the patient who was then requested to identify the two objects that shared either the same manipulation (e.g., a typewriter and a piano) or the same function (e.g., a piano and a radio). The same test was administered also verbally using written words as stimuli, according to an ABBA design. Results are reported in Table II. A.M. made more errors in 2004 than in 2002 (McNemar test, $p < .001$ for both verbal and visual versions). D.L., who was administered the test only in 2002, made errors in all subtasks. No differences between the performance in the verbal and the performance in the visual condition were found for either patient (see Table III).

Discussion

Based on the results of the naming task, the within-category and across-categories word-to-picture matching tasks, the Pyramids and Palm Trees test and the SOS, we conclude that both A.M. and D.L. had a deficit affecting their semantic memory and that this deficit is progressively worsening.

The deficit is not modality specific, as patients have comparable difficulties when pictures and words are used as stimuli. Moreover, the logistic regression analyses revealed an influence of word frequency on naming accuracy, and patients' performance was consistent over time. The multi-modality of the deficit, the word-frequency effect and the consistency across evaluations are three criteria that Warrington and Shallice (1979) proposed for correctly diagnosing a semantic deficit at the central level, as opposed to a mere deficit in accessing semantics. Thus there is a possibility that deficit of A.M. and D.L. is within the semantic system rather than in accessing it.

Apraxia Assessment

Ideational Apraxia (De Renzi and Lucchelli, 1988)

This test is commonly used in the clinical assessment for establishing the presence IA. Patients are asked to show how they would use seven common objects. For each item, 2 scores are assigned if patients perform correctly on the first attempt, 1 if they succeed on the second attempt, and zero if they fail on all occasions (maximum score = 14). In 2002 both patients performed normally but in 2004 they both made a few errors thus falling below the normal cut-off (see Table IV).

Ideomotor Apraxia (De Renzi et al., 1980)

This test has been devised in order to diagnose the presence of ideomotor apraxia, defined as a selective deficit in imitating actions. Patients were requested to imitate the gestures performed by the examiner. They were given three attempts to imitate an action correctly, scoring from 3 to 0 points, for a maximum of 72. A.M. was borderline in 2002, whereas in 2004 she performed below the cut-off, being unable to imitate both meaningful (e.g., the sign of the cross and the military salute) and meaningless actions, such as alternating the fist and the open palm consecutively. D.L. performed within the normal range in both evaluations (see Table IV).

TABLE IV

A.M.'s and D.L.'s results on the clinical assessment of praxis

			A.M. 2002	A.M. 2004	D.L. 2002	D.L. 2004	Cut-off
Praxis	Imitation	Ideomotor apraxia (De Renzi et al., 1980)	60/72	**48/72**	67/72	64/72	53
	Object use	Ideational apraxia (De Renzi and Lucchelli, 1988)	14/14	**10/14**	14/14	**11/14**	14

Note. The bold character indicates pathological scores.

TABLE V

Results on Experiment 3 (Object general semantics)

	D.L.			A.M.			
	2002		2004	2002		2004	
	Verbal	Visual	Visual	Verbal	Visual	Verbal	Visual
Raw score	**113/131**	**119/131**	**107/131**	**111/131**	**109/131**	**89/131***	**96/131**
%	**86%**	**91%**	**81%**	**85%**	**83%**	**67%**	**73%**
Z scores	**(z = – 20)**	**(z = – 8.4)**	**(z = – 17.5)**	**(z = – 22.3)**	**(z = – 16)**	**(z = – 47.7)**	**(z = – 25.8)**

Note. Z-scores are calculated based on the control group. Symbol * indicates scores significantly worsened in 2004 evaluation (McNemar test, p < .05). The bold character indicates pathological scores.

Experiment 1: Object Use

A.M. and D.L. were asked to show the correct use of twenty-three common objects (see Appendix I) performing 21 actions (see Appendix II). Performance of A.M. and D.L. was videotaped and subsequently scored by two independent judges and use was classified as correct/incorrect with 0 or 1 score. Even partially incorrect actions (e.g., doing the correct distal movement but holding the object in a clumsy fashion, or vice-versa) were scored as 0. The inter-rater agreement revealed no discordances between the two raters (Kappa-Cohen test, p > .05 for all comparisons). A.M. scored 20/22 (91%) in 2002, and 19/23 (83%) in 2004, indicating that her ability to perform everyday activities with common objects was largely preserved (McNemar test, p > .05). D.L. performed flawlessly (23/23; 100%) in 2002, and two years later he could use 20/23 (87%) objects correctly (McNemar test, p > .05), six[1] of which he claimed he did not know what they were. However, when he was persuaded to try, he resulted surprisingly skilful. According to the error classification criteria put forward by De Renzi and Lucchelli (1988) and Rumiati et al. (2001), A.M. in 2004 made two *omissions* and two *mislocations*[2]. In contrast, D.L. refused to use three objects (orange squeezer, pencil sharpener and cigarette) even after several requests made by the experimenters.

Under normal circumstances, healthy individuals are at ceiling when they use familiar objects, making no errors. These findings indicate that both patients' ability to use objects did not decline significantly over time, despite a trend toward worsening.

Experiment 2: Object Naming

Patients were requested to name the same 23 objects used in Experiment 1, without the possibility to touch them. A.M. named 15/23 (65%) objects in 2002 and 11/23 (48%) in 2004, with no significant difference between the two evaluations (McNemar test, p > .05). D.L. named 13/23 (56%) and 2/23 (9%) objects in 2002 and 2004 respectively, indicating that his lexical retrieval worsened dramatically during this period (McNemar test, p < .001).

Experiment 3: General Semantics

Coloured pictures of objects (n = 22) as well as their written names (n = 22) were presented to patients and controls, one at a time on a single card. The 22 items were the same as in Experiment 1 except for the matchbox. Five or six questions were posed orally to the subjects for each item without giving them any feedback (see Laiacona et al., 1993), for a total of 131 questions for both visual and verbal condition. For the item *"hammer"* the questions asked were the following:

– General superordinate: *Is it an object, an animal or a plant?*

– Same category superordinate: *Is it a tool, a musical instrument or a precious stone?*

– Perceptual subordinate *Is it made in glass, in metal or in cement?*

– Comparative perceptual subordinate: *Is it smaller than a screw?*

– Associative functional subordinate: *Is it used for screwing, for cutting or for driving nails?*

– Associative contextual subordinate: *Is it used by the painter, by the carpenter or by the glassworker?*

Patients' accuracy on the semantic questionnaire is summarised in Table V. Comparing patients' evaluations in 2002 and 2004, A.M.'s performance when words where used as stimuli worsened with time (McNemar test, p < .05). In contrast, in 2004 D.L. did not show a significant decrease in performance compared to 2002 (McNemar test, p > .05). Compared to the control group, A.M. and D.L. performed pathologically in all conditions, both in 2002 and in 2004 (Z scores are reported in Table V). The differences in performance on the visual and the verbal versions of the test were not found significant for either patient (see Table III).

Experiment 4: Knowledge of Parts

In this experiment a set of 46 questions concerning the functions of different parts of the

[1]Toothbrush, light bulb, match and matchbox, key and padlock, screwdriver, comb.

[2]*Mislocations*: she turned the socket instead of the light bulb; she placed the spanner above the bolt head. *Omissions:* she did not remove the cap of the toothpaste before squeezing it onto the toothbrush; she tried to open the padlock without inserting the key.

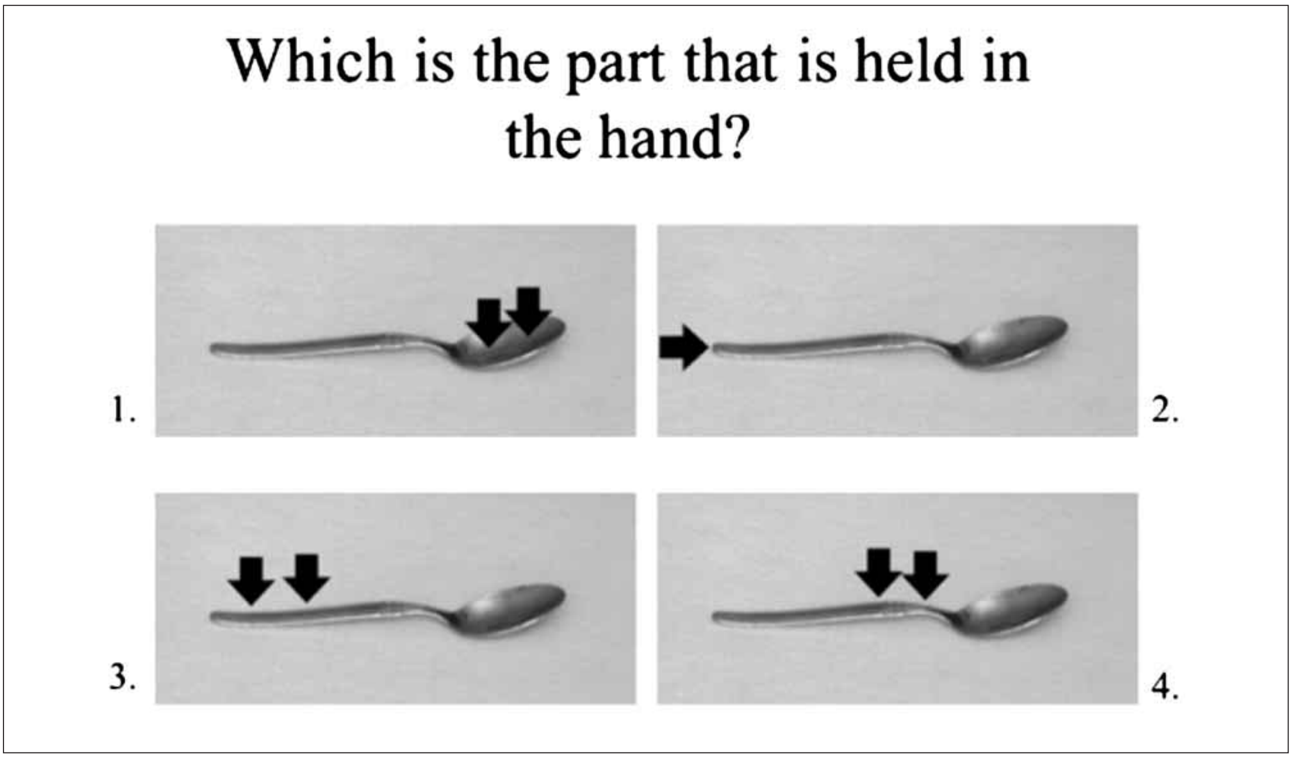

Fig. 4 – *Example of the stimuli used in Experiment 4 (knowledge of parts). Participants were asked to point to the picture corresponding to the sentence written on the top of the page while the sentence was read aloud by the experimenter.*

same 23 stimuli used in Experiment 1, were read aloud by the experimenter. For each question, patients and control subjects (n = 20) were presented with four colour photographs of identical objects differing only in the position of arrows pointing to different parts of the object itself (see Figure 4). They were required to point to the photograph with the arrows indicating the part of the object corresponding to the described function. A.M. scored 8/23 (35%) in 2002 (z = -5.7) and 9/23 (39%) in 2004 (z = -5.1), and D.L. 16/23 (69%) in 2002 (z = -2.5) and 13/23 (57%) in 2004 (z = -3.1). The difference in performance between the two sessions was not significant for either patient (McNemar test, p > .05).

A.M. and D.L. performed worse than the control group in both evaluations but their accuracy did not decrease significantly in the second as compared to the first evaluation.

Experiment 5: Manipulation Knowledge

In this experiment patients and the twenty controls saw on a computer screen either the photographs of 20 objects used in Experiment 1 or, in a different block, their names, as well as three videotaped pantomimes, each lasting about 6 seconds, in sequence. Their task was to say which video demonstrated the correct use of the target object.

In 2002, A.M. identified correctly 11/20 (55%) manipulations in the verbal condition (z = – 10.9) and 17/20 (85%) in the visual condition (z = – 2.9), whereas in 2004 she scored 14/20 (70%; z = – 6.9) in the verbal (McNemar test, p > .05) and 9/20 (45%; z = – 13.1) in the visual condition (McNemar test, p < .01). The difference in accuracy between verbal and visual condition was not significant neither in 2002 nor in 2004 (see Table III).

In 2002, D.L. identified 16/20 (80%) manipulations in the verbal condition (z = – 4.26) and 18/20 (90%) in the visual condition (z = – 1.64), whereas in 2004 he scored 12/20 (60%; z = – 9.3) in the visual condition (McNemar test, p > .05). There was no difference between verbal and visual presentation (see Table III). The verbal version was not administered in 2004.

These results indicate that, compared with normal controls, the two patients were impaired at accessing action schemas from names and pictures of objects.

Further Analyses

Object Use and Semantics

In this section, performance on the object use (Experiment 1) has been compared to that on the other experiments in which different aspects of object knowledge were tested (on a Wilcoxon signed rank test). The results are summarised in Table VI. Object use was significantly better than performance on many of the other experimental

TABLE VI

*P-values associated to a Wilcoxon signed rank tests are reported. In this test A.M.'s and D.L.'s performance on object use was compared to performance on the other experiments. Given the high number of comparisons, the α value was set at .01. The key result is that performance on object use is better than that on the other tasks in most contrasts**

	Object use (Exp. 1)			
	A.M.		D.L.	
Experiment	2002	2004	2002	2004
Exp. 2 (object naming)	n.s.	n.s.	< .01	< .001
Exp. 3 (general semantics/words)	< .01	< .001	< .001	n.a.
Exp. 3 (general semantics/pictures)	< .01	< .001	< .001	< .05
Exp. 4 (semantic of parts)	< .01	n.s.	< .01	n.s.
Exp. 5 (manipulation/words)	n.s.	n.s.	n.s.	n.a.
Exp. 6 (manipulation/pictures)	n.s.	n.s.	n.s.	n.s.

*n.a. = not administered; n.s = not significant.

tasks. Patients' ability to use objects and that to choose their correct manipulation (Experiment 5) seem to be equally affected, irrespective of whether words or pictures were used. The fact that in Experiment 5 patients were not as impaired as in the other semantic tasks, may suggest that the input action lexicon (see Rothi et al., 1991) is partially separate from verbal and visual semantic object knowledge.

Consistency Analysis Item-by-Item between Tasks

An item-by-item consistency analysis across tasks was carried out with the aim of establishing whether patients failed or succeeded with the same items across tasks, or whether the deficit randomly affected different items in different tasks. None of the statistical tests led to a significant result (see Table VII), clearly indicating that the lack of semantic and functional knowledge about objects does not necessarily prevent correct object use.

General Discussion

In this paper we discussed the performance of two patients, A.M. and D.L., whose general cognitive abilities as well as semantic and motor knowledge about a set of objects were assessed in two evaluations, in 2002 and in 2004. The neuropsychological investigation revealed that patients had a semantic impairment but relatively normal non-verbal intelligence, visual and spatial short-term memory, visual processing and praxis (see Tables I-III). While D.L.'s severe language deficits remained his prominent impairment over the period in which he was examined, with little change in his general cognitive abilities, A.M. showed a more general deterioration in the second evaluation, involving also visuo-perceptual skills and praxis abilities. Given the extending of the impairment to non-semantic functions, the case of A.M. is better described as a patient with a dementia of Alzheimer type with an atypical onset, whose early signs of pathology were focal and

TABLE VII

*Consistency analysis comparing the performance in object use with the other experiments. Object use can be considered largely independent from the other abilities**

	Object use (Exp. 1)			
	A.M.		D.L.	
Experiment	2002	2004	2002	2004
Exp. 2 (object naming)	C = .29 Chi-square = 1.95 p > .01	C = .20 Chi-square = 1.01 p > .01	C = .22 Chi-square = 1.23 p > .01	C = .14 Chi-square = .46 p > .01
Exp. 3 (general semantics/words)	C = .04 Chi-square = .04 p > .01	C = .10 Chi-square = .22 p > .01	C = .13 Chi-square = .37 p > .01	n.a. in 2004
Exp. 3 (general semantics/pictures)	C = .23 Chi-square = 1.21 p > .01	C = .08 Chi-square = .15 p > .01	C = .15 Chi-square = .56 p > .01	C = .04 Chi-square = .04 p > .01
Exp. 4 (semantic of parts)	C = .29 Chi-square = 1.99 p > .01	C = .32 Chi-square = 2.62 p > .01	C = .28 Chi-square = 2.09 p > .01	C = .06 Chi-square = .08 p > .01
Exp. 5 (manipulation/words)	C = .35 Chi-square = 2.59 p > .01	C = .05 Chi-square = .06 p > .01	C = .37 Chi-square = 3.36 p > .01	n.a. in 2004
Exp. 6 (manipulation/pictures)	C = .15 Chi-square = .42 p > .01	C = .20 Chi-square = .81 p > .01	C = .48 Chi-square = 6.3 p >.01	C = .34 Chi-square = 2.55 p > .01

*n.a. = not administered; n.s = not significant.

involved primarily language skills (see Galton et al., 2000; for a similar case Greene et al., 1996). The magnetic resonance performed in 2005 seems to support this interpretation showing a diffused cortical atrophy. Despite the fact that in 2004 A.M.'s deficit was no "purely" semantic anymore, the strong dissociation (see Shallice, 1988) between object use and object knowledge remained significant.

Overall the experimental study showed that patients' performance on object use (Experiment 1) was significantly better than that on tasks tapping verbal and semantic knowledge about objects (Experiments 2-4), showing a strong dissociation (see Shallice, 1988) but it was as impaired as the ability to choose the correct manipulation of objects (Experiment 5) (see Table VI). Nevertheless, an item-by-item consistency analysis (Table VII) showed that patients were able to use also objects (Experiment 1) for which they did not retain general semantic knowledge at all (Experiments 3 and 5) or even functional knowledge of their parts (Experiment 4). For example, when requested to use a spanner, a match, a key and a light bulb, after showing distress for he did not know what those objects were, D.L. managed to use them correctly. Though it could be argued that object use may also rely on a non-semantic route in which affordances are elicited directly from the object structure (see Hartmann et al., 2005; Hodges et al., 2000; Goldenberg and Hagmann, 1998; Gibson, 1977), this explanation cannot account for instances in which object manipulation cannot be inferred from its shape. For example, in 2004, when a match – whose purpose and use cannot be readily inferred from its shape and structure – was posed in front of D.L., he said: "I don't know, I've never seen it before and I do not even know what this thing is used for". Nevertheless, when the experimenter asked him to try to use it anyway, he could light it by scratching it against the matchbox, and then he blew it out correctly. Note that this is a task in which IA patients are highly prone to errors, despite their intact object knowledge about the objects presented (see Rumiati et al., 2001). In addition, D.L. in 2004 clearly showed to know very little about the aforementioned objects, as he failed to name them in Experiment 1 or answer specific questions concerning them in the Experiments 3-5. Similarly, in 2004 A.M. was able to use six objects for which formal testing demonstrated that she did not retain semantic, functional and manipulation knowledge (Experiments 3-5). Thus our findings are at variance with the claim that the conceptual knowledge and problem solving abilities play a critical role in determining the success of object use (Bozeat et al., 2002b; Hodges et al., 2000; Coccia et al., 2004; Goldenberg and Hagmann, 1998).

Gibson (1977) proposed the term *affordance* to indicate a characteristic of the object that triggers online how to manipulate or grasp it. For instance, the grooves of a light bulb should elicit the action of turning the bulb in its socket. D.L., however, seems to be able to manipulate *also* those objects for which the shape can hardly afford their specific use such as a match and a comb. Not only could he hold them correctly, but he could also perform the appropriate movement when asked to use them. Based on these observations, we think that a most suitable interpretation for our results is offered by the view of Ellis, Tucker and coworkers (Grèzes et al., 2003; Tucker and Ellis, 2001 and 1998; Ellis and Tucker, 2000) who proposed that affordances are object-action associations stored in memory rather than computed online.

In the contest of the action selection model proposed by Norman and Shallice (1980; see also Cooper and Shallice, 2000; Cooper et al., 2005), A.M.'s and D.L.'s preserved object use indicate that the action network is unimpaired, as the appropriate action schemas are selected.

A.M.'s and D.L.'s ability to use objects did not decline significantly from the 2002 to the 2004 evaluation, even though in 2004 their performance on object use was not as good as that of healthy controls, suggesting an initial breakdown. In contrast, their conceptual knowledge resulted to be severely affected in all the clinical and experimental tasks already in the first evaluation (2002). Since patients' performance was already pathological in 2002, we failed to find a statistically significant decay over time, but we did observe an important clinical decline (as confirmed by their z-scores). Moreover, the semantic knowledge was affected irrespective of the modality assessed. Indeed there was no difference in performance between verbal and visual versions in the tasks that employed both versions as stimuli (Experiments 3, 5 and the SOS) (see Table III). This suggests that D.L. and A.M. had a deficit affecting the verbal as well as the visual semantics (Hodges et al., 1992; Snowden et al., 1989; Warrington, 1975).

Conclusion

Some authors have argued that patients who are still able to use objects despite having a semantic loss may rely on visual and/or tactile affordances or on trials and errors strategies (e.g., Hodges et al., 2000), and that the loss of knowledge about an object is generally associated with the failure in its use (e.g., Coccia et al., 2004; Bozeat et al., 2002a, 2002b; Hodges et al., 2000). Our findings seem to be at variance with the above view: we propose that the semantic and motor knowledge of an object, although they usually interact, may be represented separately in the brain. In our patients the two abilities seem to decline independently. A.M. and D.L.'s performance on object use is significantly better than on other semantic tasks and they are still able to use objects for which the semantic properties are lost. Their failure on object use is not simply because this task is easier than the semantic tasks, as their performance double dissociates (see Shallice, 1988) with that found in patients with IA, in whom the ability to use objects is impaired despite a preserved semantic knowledge about the same objects (Rosci et al., 2003; Rumiati et al., 2001; Rapcsak et al., 1995; Schwartz et al., 1995). The object-actions associations can be seen as motor properties of a distributed object representation and they are held to be at fault in IA patients (see Rumiati et al., 2001), whereas they are preserved in A.M. and D.L.

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Appendix I

List of the 23 objects used in Experiments 1-5

1	Knife
2	Squeezer
3	*Pencil*
4	Glass
5	Tea spoon
6	Cigarette
7	Match
8	Hammer
9	Pencil sharpener
10	Mug
11	Teapot
12	Saw
13	Scissors
14	*Nail*
15	Pliers
16	Screwdriver
17	Spanner
18	Axe
19	Comb
20	Toothbrush
21	Key
22	Lightbulb
23	*Match box*

Note. Items in italics were not used in Experiments 3-5.

Appendix II

List of actions that patients were required to perform in Experiment 1 (object use). Object(s) were posed in front of the patients who were asked to use them, without any further instruction

1	Cutting an orange with a knife
2	Squeezing an orange with the squeezer
3	Pouring the juice from squeezer to glass
4	Drinking from the glass
5	Pouring from a teapot into a mug
6	Stirring sugar with a teaspoon in the mug
7	Screwing (screwdriver + screw)
8	Cutting a wooden board with an axe
9	Putting toothpaste onto a toothbrush
10	Brushing teeth
11	Using a pencil sharpener and pencil
12	Using a spanner and a bolt
13	Cutting paper with scissors
14	Screwing a light bulb
15	Hammering a nail in a wooden board
16	Sawing a wooden board
17	Lighting a match (match + matchbox)
18	Lighting a cigarette (match + cigarette)
19	Removing a nail with pliers
20	Combing oneself
21	Using a key (key + padlock)