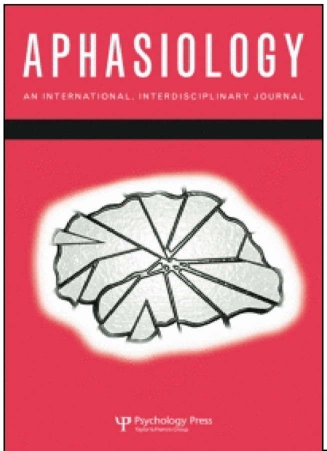

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Reacquisition of semantic knowledge by errorless learning in a patient with a semantic deficit and anterograde amnesia

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Reacquisition of semantic knowledge by errorless learning in a patient with a semantic deficit and anterograde amnesia

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Background: So far 11 therapy studies have been reported which aimed to re-teach semantic knowledge in brain-damaged patients presenting with a semantic deficit consecutive to stroke, herpes encephalitis, or semantic dementia. All these semantic therapy studies but one recorded a significant improvement in the patients' performance on tasks requiring semantic processing. The exception to this pattern was the semantic therapy study by Sartori, Miozzo, and Job (1994), which yielded negative results. Because the study concerned two patients with anterograde amnesia associated with the semantic deficit, Sartori et al. concluded that reacquiring semantic knowledge was not possible when such association of deficits was present.

Aims: Sartori et al.'s study, like all the other semantic therapy studies, applied an errorful learning procedure during the therapy. However, the question can be raised of whether such procedure is appropriate when amnesia is associated with the semantic deficit. Because error elimination is likely a function of explicit memory, which is impaired in amnesic patients, wrong stimulus–response associations would be repeatedly retrieved and strengthened in (spared) implicit memory, thus preventing the patient from learning novel semantic knowledge. In the present single-case study we addressed this issue by using an errorless learning procedure during semantic therapy in a post-encephalitis patient (DL) who suffered both a semantic deficit and anterograde amnesia.

Methods & Procedures: The therapy aimed at re-teaching semantic attributes of 16 items. The design included, further to these 16 target items, 16 contrast and 16 control items, which were semantic coordinates of the target items. Both shared (category) and distinctive (non-category) attributes were included in the learning set. Learning was based on an attribute classification task in which the properties of the target items had to be contrasted with those of coordinate items, within a paradigm that greatly reduced the chance of making errors. A pre- and post-therapy picture naming and an attribute verification task allowed us to assess the therapy effects at the end of therapy and 1 year later.

Outcomes & Results: Significant therapy effects were observed in the attribute verification task and were still present 1 year afterwards. Thus, the patient's performance significantly improved for the category (i.e., shared) attributes of the target, contrast, and control items, and for the non-category (i.e., distinctive) attributes of the target items.

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Conclusions: This finding showed that, contrary to Sartori et al.'s claim, re-acquiring semantic knowledge was possible in a patient with anterograde amnesia associated with her semantic deficit.

Brain damage resulting from stroke, head injury, herpes simplex virus encephalitis (HSE), or degenerative disease, may cause chronic and sometimes very severe semantic impairments. Patients thus show poor performance in a number of tasks that are thought to require access to semantic knowledge, like object or picture naming, object recognition and utilisation, word or picture categorisation, word-to-picture matching or category fluency tasks. The detailed study of the patterns of semantic impairment presented by such patients has given rise to a voluminous literature during the last two decades and provided the main source of evidence for the theoretical issue of how semantic knowledge is represented and organised in the normal mind and brain (e.g., Allport, 1985; Buxbaum, Schwartz, & Carew, 1997; Chertkow, Bub, Deaudon, & Whitehead, 1997; Damasio, Tranel, Grabowski, Adolphs, & Damasio, 2004; Farah & McLelland, 1991; Hillis, Rapp, Romani, & Caramazza, 1990; Mahon & Caramazza, 2003; Riddoch, Humphreys, Coltheart, & Funnel, 1988; Rogers et al., 2004; Samson & Pillon, 2003).

Less attention has been paid to the issue of whether, to what extent, and how semantic knowledge could be relearned after brain damage. To the best of our knowledge, 11 papers (see Table 1) so far have reported a therapy study aiming at relearning of semantic information in patients suffering from a semantic deficit (for reviews, see Nickels, 2002; Nickels & Best, 1996a). In these studies, the semantic properties of an object, such as its visual appearance (shape and colour), function (what it is used for), utilisation (how it is used), and associated items (which objects it is used with), are taught to the patients by asking them to describe how the object looks, to point to the object from a verbal definition, use it on imitation, etc. Given that the treated patients often presented word-finding difficulties in addition to the semantic deficit, in most studies the semantic therapy tasks were associated or followed by tasks aiming at improving spoken and/or written word retrieval (see details in Table 1). As an illustration, take Drew and Thompson's (1999) therapy study, which aimed at restoring semantic information about 30 items of clothing and 30 items of food, in four aphasic patients. To measure within-category and across-category transfer effects, 15 additional items of clothing and food and 15 items of animals and vehicles were selected as control items, which were not trained during therapy. The therapy consisted of presenting the target items to the patients in the context of several lexical and semantic tasks such as picture categorisation, semantic judgement, definition-to-picture matching, written word-to-picture matching task, and naming to definition. In the first phase of the study the name of the target items was never provided to the patients (semantic treatment), whereas in the second phase both the spoken and written names of the items were used in the therapy tasks (lexical-semantic treatment). For example, in the semantic treatment phase the patients were asked, in front of a picture depicting a watch, "Is this used to tell the time?" (semantic judgement), whereas in the lexical-semantic treatment phase they were asked "Is the *watch* used to tell the time?". At the end of the semantic phase, two of the four patients presented a significant improvement in naming the target items, and at the end of the lexical-semantic phase, naming performance significantly improved in all the patients. However, improvement did not generalise to within- or across-category untrained

TABLE 1
List of the semantic therapy studies[(a)]: Summary of the methods

	Subjects		Methods		
References	*Patients*	*Aetiology*	*Baseline tasks*	*Semantic therapy tasks*	*Additional therapy tasks*
Annoni et al., 1998	JHN GE	Stroke Stroke	Spoken picture naming	Spoken and written picture naming, spoken and written definition-to-picture matching, word-to-picture matching.	Spoken and written word retrieval
Behrmann and Lieberthal, 1989	CH	Stroke	Semantic categorization	Explanation of the semantic features, pointing to a word from a definition, word-to-picture matching.	
Bozeat et al., 2004	JH	Stroke	Object use	Object use on imitation.	
Drew and Thompson, 1999	Subjects 1, 2, 3, 4	Stroke	Spoken picture naming	Semantic categorization, semantic judgement, definition-to-picture matching.	Spoken and written word retrieval
Francis et al., 2002	NE	Herpes encephalitis	Study 2: Familiar person naming (from pictures)	Study 2: for each photograph of a face, learning its related name and three relevant facts.	Spoken and written person name retrieval
			Study 3: Person naming (from pictures), retrieval of semantic knowledge about persons	Study 3: for each person name, learning three relevant facts.	
Hillis and Caramazza, 1994	JJ	Stroke	Spoken picture naming	Study 3: word-to-picture matching (therapy 1).	Spoken word retrieval
Kiran and Thompson, 2003	Subjects 1, 2, 3, 4	Stroke	Spoken picture naming	Spoken picture naming, semantic categorization, semantic attribute identification, yes/no questions on typical/intermediate/atypical exemplars of the trained categories.	

TABLE 1
Continued

	Subjects		*Methods*		
References	*Patients*	*Aetiology*	*Baseline tasks*	*Semantic therapy tasks*	*Additional therapy tasks*
Lambert, 1999	JF	Semantic dementia	Semantic questionnaire, drawing from a name, spoken picture naming	Spoken and written definition-to-picture matching, different/similar judgement, word listening.	Spoken and written word retrieval
Nickels and Best, 1996b	AER	Stroke	Spoken picture naming	Judgement of function (therapy 1) and of relatedness (therapy 2); word-to-picture matching (therapy 3).	
	TRC	Stroke	Written and spoken picture naming	Written (therapy 1) and spoken (therapy 2) word-to-picture matching.	
	PA	Stroke	Spoken picture naming	Picture naming on letter cues (therapy 1), written word-to-picture matching (therapy 2).	
Sartori et al., 1994	Michelangelo Giulietta	Herpes encephalitis	Spoken picture naming, part-whole matching, object decision task, perceptual property decision, drawing from memory	Semantic categorization, concept definition, visual feature description, naming from a definition, word-to-picture matching, drawing.	
Vish-Brink et al., 1997	Subject A Subject B	Stroke Stroke	Aachener Aphasic Test, Semantic Association Test	Semantic foil detection, semantic association, definition-adjective matching.	

(a) We only considered here the therapy studies (1) that demonstrated the presence of a semantic deficit in the patients treated, by formal semantic testing and (2) of which explicit aim was to restore semantic knowledge. Thus, we did not report here the therapies that did not assess semantic processing formally (i.e., Doesborgh, van de Sandt-Koenderman, Dippel, van Harskamp, Koudstaal and Vish-Brink, 2004) nor the therapies that targeted word-finding difficulties and used only naming tasks during therapy.

items after the first phase. After the second phase, naming improved for untrained within-category (clothing and food) items in three patients and to untrained across-category (animals and vehicles) items in one patient. Nine weeks after therapy, the patients' naming performance decreased but was still better than before therapy.

Actually, the extent of transfer (i.e., within- or across-category items) and of maintenance of the therapy effects (i.e., from 1 week to 6 months post-therapy) differed across the 11 studies on record—nevertheless beneficial effects were obtained in all but one study (see details in Table 2). Such a general positive finding is worth noting given the large differences existing across studies regarding the lesion aetiology in the treated patients (i.e., HSE, stroke, or semantic dementia), the targeted semantic categories (i.e., persons, living, and/or nonliving things), the nature of the learning tasks (e.g., object definition or object use), or the baseline tasks (e.g., picture naming or semantic categorisation). That shows that semantic knowledge could indeed be re-acquired after brain damage whatever the aetiology, the category of items, and the nature of the tasks included in the therapy.

The sole exception to the general pattern of positive finding is the study by Sartori et al. (1994), carried out with two post-encephalitic patients, Michelangelo and Giulietta. Both patients presented with a semantic deficit, which was more severe for living than nonliving things, as well as anterograde amnesia. The therapy aimed at restoring semantic knowledge about some living and nonliving things, including animals, fruit, vegetables, and man-made objects, through several tasks requiring both semantic and lexical knowledge, like categorising pictures and words, defining concepts, describing the perceptual features of objects, naming from a verbal definition, word-to-picture matching, and drawing. After intensive training, which took place twice a week during 12 months in the case of Michelangelo and 8 months in the case of Giulietta, "patients' performance on the post-treatment tests revealed no significant benefit from the therapy" (Sartori et al., 1994, p. 119); i.e., both patients' performance in several standard tasks (e.g., naming the Snodgrass and Vanderwart pictures) was still below that of the control group. On the basis of this finding, the authors proposed that relearning semantic knowledge was probably not possible in these patients because of the anterograde amnesia associated with their semantic deficit.

Such pessimistic conclusion may be premature, however. To begin with, even the report of a poor outcome of the therapy needs to be qualified because, in this study, the therapy effects were not assessed on the basis of the patients' pre- and post-therapy performance on a given task (actually, different tasks were administered to the patients before and after therapy). The conclusion was based on the comparison of the patients' performance on standard tasks after therapy with that of controls. Therefore, it is not possible to know whether the therapy did not improve semantic knowledge in the patients *at all* or just did not allow them to reach normal performance. Second, the post-therapy performance was assessed 1 month after the end of the therapy and, therefore, any immediate therapy effect may have gone undetected. Third, there is at least one instance of semantic therapy with a patient presenting with associated memory impairments[1] that yielded positive results—Francis et al.'s (2002) therapy study.[2] Admittedly, this therapy concerned a quite

[1] The paper reports that the treated patient NE performed poorly on the Wechsler Memory Scale-Revised (Wechsler, 1987) and the Recognition Memory Test (Warrington, 1984) but memory functions were not assessed or characterised in more detail.

[2] In all the other successful semantic therapy studies listed in Table 1, there was no mention of memory impairment in the treated patients.

TABLE 2
List of the semantic therapy studies: Summary of the results

		Results		
References	*Subjects*	*Trained items*	*Transfer effects on untrained items*	*Follow-up*
Annoni et al., 1998	JHN GE	Naming improved for both patients	Not tested	3 weeks: + 6 months: +
Behrman and Lieberthal, 1989	CH	Semantic categorization improved for all the semantic categories	Improvement within trained semantic categories No improvement on untrained semantic categories	10 weeks: +
Bozeat and Patterson, 2004	JH	Improvement in object use	No improvement	5 weeks: +
Drew and Thompson, 1999	Subjects 1, 2, 3, 4	Improvement in picture naming for subjects 3 and 4	No improvement within trained and untrained categories for any patient	9 weeks: +
Francis et al., 2002	NE	Naming improved after Study 2 and 3	No improvement in Study 2; not tested in Study 3	Study 2: 1 week: + Study 3: not tested
Hillis and Caramazza, 1994	JJ	Naming improved	Not tested	Not tested
Kiran and Thompson, 2003	Subjects 1, 2, 3, 4	Naming improved in all subjects	Naming typical stimuli improved in subjects 1, 2, 4 after therapy on atypical stimuli	6 weeks: +
Lambert, 1999	JF	Improvement in naming and in the semantic questionnaire	No improvement	Not tested
Nickels and Best, 1996b	AER	Naming improved only after therapy 2 and 3	Improvement on untrained items after therapy 1, 2 and 3	One month (therapy 2/3): + One year (therapy 3): +
	TRC	Naming improved after therapy 1	Improvement on untrained items after therapy 1	One month: +
	PA	Naming improved after therapy 1	No improvement on untrained items after therapy 1	Interval not specified: -
Sartori et al., 1994	Michelangelo Giulietta	No improvement (semantic impairment still present one month after therapy in standard tasks) in both patients		Not tested
Vish-Brink et al., 1997	Subject A Subject B	Not tested	Improvement only in the semantic association test, not in the Aachener Aphasic Test	Not tested

+ = significantly better than pre-therapy performance on the trained items.

different domain of semantic knowledge—person-specific knowledge—and it is unclear whether learning to associate a face with semantic information about a person (e.g., occupation) relies on the same cognitive demands and mechanisms as learning the semantic attributes of a *class* of objects (i.e., learning an object concept). However, it is worth noting that the learning strategy taught to the patient, namely turning semantic information relevant to each face into a visual image, had proved successful for teaching face–name associations in amnesic patients (Wilson, 1987). Thus the question can be raised of whether the learning procedure adopted in Sartori et al.'s (1994) therapy was appropriate for patients with associated anterograde amnesia, and, in particular, whether errorless learning—instead of errorful learning which was used in that study as in all the other semantic therapy studies—would not in fact be more suitable.

There is now evidence that, in amnesic patients, training is more effective when an errorless learning approach is adopted, i.e., when participants do not experience failure during learning, than when learning is errorful, i.e., based on a trial-and-error procedure. For example, it was found that training amnesic patients to learn novel face–name associations (Parkin, Hunkin, & Squires, 1998; Wilson, Baddeley, Evans, & Shiel, 1994) or verbal lists (Hunkin, Squires, Aldrich, & Parkin, 1998a; Hunkin, Squires, Parkin, & Tidy, 1998b), or to programme an electronic organiser (Evans et al., 2000) was facilitated by adopting an errorless learning approach. According to Baddeley and Wilson (1994), the effectiveness of errorless learning in amnesic patients is based on the combination of impaired explicit memory and relatively spared implicit memory. In the context of an errorful learning situation, the functioning of implicit memory results in implicitly remembered incorrect responses interfering with the target items, and the absence of a functioning explicit memory system prevents differentiation and elimination of learning errors. This mechanism, in turn, would strength the stimulus–(wrong)response association in memory, which eventually prevents the acquisition of novel, correct responses (but for alternative views, see Hunkin et al., 1998b, Kessels, Boekhorst, & Postma, 2005).

However, as far as we know, errorless learning has never been applied during semantic therapy in patients presenting with a semantic deficit either associated or not associated with amnesia. The aim of the present single-case study was to evaluate the effectiveness of an errorless learning approach for re-teaching semantic knowledge about concrete objects to a post-encephalitic patient presenting with a semantic deficit associated with anterograde amnesia. We put forward the hypothesis that using an errorless learning procedure in a patient presenting with such an association of deficits should facilitate the reacquisition of semantic knowledge, because errorless learning should avoid wrong associations between semantic features and items being encoded and stored in implicit memory.

CASE REPORT

DL is a 58-year-old, right-handed, French-speaking woman with 10 years of formal education who was working as an international business employee when she contracted HSE at the age of 55, in June 2000. The neurological examination revealed mild left hemiparesis, right homonymous hemianopsy, fluent aphasia with jargonaphasia, and impaired auditory and visual word comprehension. At this time, DL presented complete anosognosia.

The MRI showed, on the left side, a destruction of most of the temporal lobe including the amygdala, the hippocampus, and the parahippocampal gyrus. Only the posterior part of the superior temporal gyrus was partially preserved. The whole insula, most of the rectus and orbital gyri, and the anterior and middle part of the cingulate gyrus were also destroyed. In the frontal lobe, the lesions also extended to the precentral gyrus and to the white matter of the inferior frontal gyrus. In the occipital lobe, the lesions extended to the lingual gyrus and the inferior and posterior part of the cingulate gyrus. On the right side, the lesions were much more circumscribed and concerned the insula, the inferior and anterior part of the cingulate gyrus, and part of the rectus and orbital gyri (see Figure 1).

In May 2001, DL was referred to our rehabilitation centre for treatment of her refractory left temporal epileptic seizures as well as cognitive and language rehabilitation. At that time, DL showed good neurological and neuropsychological recovery. The right hemiparesis and the anosognosia had resolved, and the aphasia had substantially improved. The neuropsychological exams primarily revealed language and memory disorders.

An extensive language assessment (*Batterie d'Evaluation du Langage, Cliniques universitaires Saint-Luc*) revealed the characteristics of transcortical sensory aphasia (Table 3). Connected speech was fluent but not informative, with frequent word-finding pauses in the context of long and syntactically correct sentences. Articulation and prosody were normal. Repetition of words from various grammatical categories and of different length and syllabic complexity was normal. Repetition of simple and complex syllables, of nonwords close or distant from words, and of short sentences of increasing grammatical complexity, was also normal. However, repetition of a longer sentence resulted in mixed (phonemic and semantic) jargon. DL was markedly anomic. In a picture-naming test composed of one-, two-, and three-syllable words of low, medium, and high frequency of usage (Vikis-Freiberg, 1974), DL was able to name only 1 out of 45 items. Her erroneous responses were circumlocutions, non-responses, neologisms, and verbal paraphasias. Phonemic cueing was not effective at all. Only 2 out of the 26 cueing trials led to a correct response, 3 led to a phonological paraphasia, and 2 to a verbal paraphasia; the remaining trials led to non-responses. On the receptive side, the discrimination of CV syllables was tested in a spoken word–picture matching task composed of four sets of five phonologically similar words: DL's performance in this test was within the normal range. However, in a semantic association task (Pyramids and Palm Trees Test; Howard & Patterson, 1992), DL's performance was below the normal range whatever the modality of presentation of the

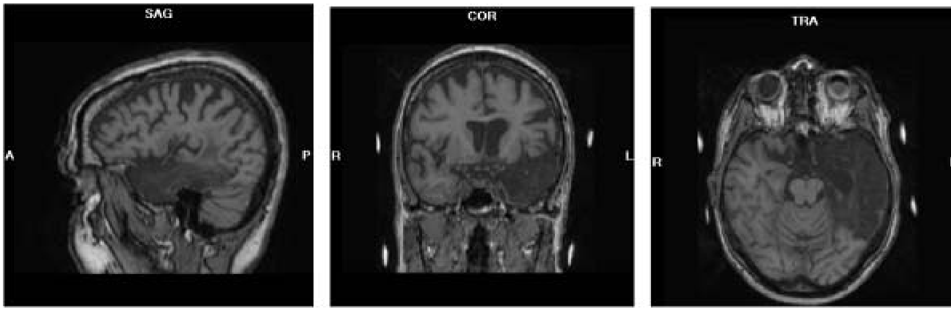


Figure 1. MRI of DL in July 2006 [sagittal, coronal, and transversal views].

TABLE 3
Language examination in DL (May 2001)

Task	*DL*	*Controls Mean (range)*
Repetition (a)		
Words	18/18	18/18 (c)
Syllables	15/15	15/15 (c)
Nonwords	5/6	6/6 (c)
Short sentences	3/3	3/3 (c)
Long sentences	0/1	3/3 (c)
Spoken picture naming (a)	1/45	Not available
Discrimination of CV syllables (a)	15/16	16/16 (c)
Pyramids and Palm Trees (b)		
Spoken words	38/52	50.5 (50–52)
Written words	39/52	50.5 (50–52)
Pictures	47/52	50.5 (50–52)
Sentence-to-picture matching (a)		
Spoken sentences	11/16	Not available
Written sentences	14/16	Not available
Spelling (a)		
Letters	7/8	8/8 (c)
Words	2/12	Not available
Nonwords	2/4	Not available
Sentences	0/4	Not available
Reading aloud (a)		
Letters	8/10	10/10 (c)
High-frequency words	6/9	9/9 (c)
Low-frequency words	3/9	9/9 (c)
4/5 letter words	5/6	6/6 (c)
9/10 letter words	2/6	6/6 (c)
Words vs. nonwords	4/10 vs. 0/10	10/10 vs. 10/10 (c)

(a) *Batterie d'Evaluation du Langage (Cliniques universitaires Saint-Luc)*
(b) Howard and Patterson (1992)
(c) Normative data taken from a control group of 83 subjects of various education (6 to 12 years of formal education) and age (18 to 69).

items (spoken or written words, or pictures, although she had better scores with pictures). DL's syntactic comprehension was good. In an auditory and a written sentence-to-picture matching test with non-reversible and reversible active, passive, and relative sentences, her errors only consisted in choosing the lexical foils. As regards spelling, DL could copy and write on dictation single letters. However, she was impaired in writing on dictation a list of high- and low-frequency words (Juilland, Brodin, & Davidovitch, 1970) of five and eight to nine letters in length and various levels of orthographic regularity. Her spelling performance was also impaired for nonwords and sentences. DL's spelling errors for both words and nonwords consisted of nonword letter-strings composed of the same number of letters as the target and sharing with that target the first letters. In reading aloud, DL quite correctly read single letters but her reading of words was very poor, with high-frequency words being more accurate than low-frequency words, and four- and five-letter words more accurate than nine- and ten-letter words. Words were read better than nonwords matched for length. For all types of items, reading errors were phonological errors.

Neuropsychological examination identified other impairments (Table 4). In short-term memory tasks, DL's performance was impaired for verbal material (digit

TABLE 4
Neuropsychological examination in DL

Task	*DL June 2001*	*DL March 2003*	*Controls' mean*	*DL's z-score or percentile*
Short term memory				
Digit span (a)	3			−3.82 SD
Block tapping (b)	4			Percentile 10
Episodic memory				
Doors and People Test (c)				
Part A	9/12			Percentile 10
Part B	3/12			Percentile 1
Free and Cued Selective Reminding test (d)				
Immediate recall		11/16	15.7	−6.7 SD
Free recall 1		5/16	9.4	−1.7 SD
Total recall 1		7/16	14.8	−4.6 SD
Free recall 2		7/16	10.3	−1.3 SD
Total recall 2		9/16	15.3	−5.2 SD
Free recall 3		5/16	12.1	−2.3 SD
Total recall 3		9/16	15.5	−7.2 SD
Recognition test		14/16	15.7	−2.4 SD
Delayed free recall		0/16	12.2	−4.5 SD
Delayed total recall		n.a.	15.7	n.a.
Problem solving				
Raven Matrix (e)	QI 100		QI 100	

n.a. = non administered
(a) Wechsler (2000)
(b) Smirni, Villardita and Zappala (1983)
(c) Baddeley, Emslie and Nimmo-Smith (1994)
(d) Buschke (1984)
(e) Raven, Court and Raven (1998).

span = 3) and poor for spatial material (spatial span, measured with a block-tapping test = 4; Percentile 10). In addition, DL showed an impairment in visual episodic memory. On the Doors and People Test (Baddeley, Emslie, & Nimmo-Smith, 1994), she scored 9/12 (Percentile 10) on the first and easy part of the test, and 3/12 (Percentile 1) in the second and complex part. There was no evidence of mental deterioration, i.e., no impairment in solving complex problems (Raven Matrix test: QI = 100), acalculia, or apraxia. No sign of frontal dysfunction was observed, either in formal testing or in social behaviour.

At the time of the therapy study presented below (July–August 2003), DL still presented severe language impairments (see Case Analysis) and anterograde memory deficits. Before therapy, verbal episodic memory was tested with the "Free and Cued Selective Reminding test" (Buschke, 1984). This task, composed of 16 written words, includes a cued immediate retrieval subtest and three free and cued retrieval subtests, as well as a recognition and a delayed retrieval subtest. Because of DL's spoken output limitation, phonological paraphasias (at least 50% of the phonemes in common with the target) were considered as correct responses. DL's performance was poor whatever the subtest. Even if these results have to be interpreted with caution because of DL's associated semantic and spoken output deficit, it is likely that she presented at least a mild verbal episodic memory deficit, since her performance in the recognition subtest, which is not semantically nor productively demanding, was impaired as well. However, she remained competent in a number of everyday tasks, although her use of some objects and her cooking repertoire was limited and/or stereotyped.

CASE ANALYSIS

Language examination revealed that DL was severely anomic. As mentioned in the previous section, she was able to name only 1 item in a 45-item picture naming test (*Batterie d'Evaluation du Langage, Cliniques universitaires Saint-Luc*). Moreover, her impaired performance for both the verbal and the picture version of the semantic association task (Pyramids and Palm Trees Test) suggested the presence of a semantic impairment. Thus, it is likely that DL's anomia was at least partly due to loss of semantic knowledge. In this section we report a more thorough and detailed analysis of DL's performance across a number of tasks aiming, first, to determine whether additional deficits located at pre-semantic or/and post-semantic levels of processing could contribute to her impaired performance in the naming and the association task, and, second, to provide a more detailed characterisation of her semantic impairment. Also, the results of this analysis were useful for designing the therapy procedure and choosing the appropriate baseline tests.

Most of the following tasks were administered during an 11-month period (June 2001–May 2002). However, given that the therapy study was conducted in July–August 2003, six tasks (see Table 5) were re-administered in March 2003 in order to check the stability of the patient's performance.

Naming and comprehension of the same set of 80 items

DL's performance in naming and comprehension was assessed in a picture-naming and a spoken and written word-to-picture matching task composed of the same set of 80 items, drawn from both living and nonliving semantic categories (*LEXIS*; de Partz, Bilocq, de Wilde, Seron, & Pillon, 2001). In the picture-naming task, DL had to provide the spoken name for each of the 80 objects depicted in black-and-white line drawings within a 20-second time limit. The following week the same items were presented to her in a spoken and a written word-to-picture matching task. Each of the 80 spoken or written words was simultaneously presented with a set of five pictures—that is, the target and four foils—which were either visually related, semantically related, both visually and semantically related, or unrelated to the target. DL was asked to point to the picture corresponding to the spoken or the written word.

DL's performance was severely below the normal range in the three tasks (see Table 5). At both presentations of the picture-naming task (2001 and 2003), the patient's erroneous responses mainly consisted of non-responses, circumlocutions, and neologisms; there were also occasional phonological paraphasias and *conduites d'approche* as well as some semantic paraphasias (see Table 6). In both versions of the picture–word matching test, DL's errors mainly consisted of choosing the foil that was both visually and semantically related to the target (spoken version, $n = 13$; written version, $n = 10$) and, to a lesser extent, the semantically related (spoken version, $n = 4$; written version, $n = 5$) or visually related ($n = 1$ and $n = 2$, respectively) foil. In 2003, the spoken version of the test was administered again

TABLE 5
DL's and controls' scores in several tasks assessing lexical and semantic processing

Task	*DL June 2001*	*DL March 2003*	*Controls' mean (SD or range)*
45-item picture naming	1/45	0/45	
Picture naming (a)	2/80	6/80	75.1 (2.17)
Word-picture matching (c)			
Spoken words	62/80	62/80	79.3 (0.46)
Written words	55/80		
Pyramids and Palm Trees (b)			
Spoken words	38/52		50.5/52 (50–52)
Written words	39/52		50.5/52 (50–52)
Pictures	47/52	47/52	50.5/52 (50–52)
Picture categorization (d)			
Spoken words			
Distant categories	35/36		36/36
Close categories	32/36		36/36
Written words			
Distant categories	30/36		36/36
Close categories	23/36		36/36
Pictures			
Distant categories	34/36	31/36	36/36
Close categories	33/36	36/36	36/36
Word-picture verification (e)			
Living things	18/36	16/36	33.25/36 (30–35)
Animals	8/18	7/18	16.25/18 (15–18)
Fruit/vegetables	10/18	9/18	17/18 (15–18)
Non-living things	20/36	18/36	31.5/36 (28–34)
Implements	10/18	9/18	16.25 (15–18)
Transport	10/18	9/18	15.25 (12–17)
Synonym pointing (f)			
Concrete nouns	19/30		29.4/30 (29–30)
Concrete verbs	23/30		29.4/30 (28–30)
Abstract nouns	18/30		27.8/30 (25–29)
Abstract verbs	21/30		28.2/30 (26–30)

Normative data are taken from : (a, c) de Partz et al. (2001) ; (b) Howard and Patterson (1992) ; (d) a control group of ten subjects matched to DL for age and education; (e) Samson et al. (1998); (f) a control group of five subjects matched to DL for age and education.

and DL obtained identical scores (62/80). The rate of her consistent responses across both presentations (both correct or both wrong for a given item) was 69%, which was a quite high degree of intra-item consistency across time.

Pre-semantic processing

Visual processing. DL's scores were within the normal range on all the tasks of the BORB (Birmingham Object Recognition Battery; Riddoch & Humphreys, 1993), including the object decision task (Task 10), where her scores (104/128) were at the lower normal limit (normative mean: 114.7, $SD = 5.7$). Moreover, DL's performance was not influenced by the structural complexity of the stimuli. She performed within the normal range on the two difficult parts of the task (DL: 27/32 and 30/32;

TABLE 6
Distribution of DL's erroneous responses in the spoken naming test of the LEXIS in 2001 and 2003

	Spoken naming 2001	*Spoken naming 2003*
Non-responses	33 (42.3%)	28 (38.2%)
Circumlocutions	13 (16.7%)	14 (18.9%)
Neologisms	10 (12.8%)	4 (5.4%)
Phonological paraphasias and *conduites d'approche*	7 (9%)	9 (12%)
Verbal paraphasias	6 (7.7%)	3 (4%)
Semantic paraphasias	5 (6.4%)	12 (16.1%)
Mixed paraphasias	1 (1.3%)	2 (2.7%)
Ambiguous	3 (3.8%)	2 (2.7%)

Circumlocutions: Sentences defining the target word. They were not very informative in DL; e.g., she said "*il faut le prendre*"/"it has to be taken" for the target item *valise*/suitcase.

Neologisms: Nonwords that presented no formal similarity with the target; e.g., /sampl/ for the item *assiette*/plate.

Phonological paraphasias: Nonwords that shared at least 50% of the phonemes with the target word; e.g., /pHtalH/ for the item *pantalon*/trousers.

Conduites d'approche: Nonwords corresponding to the first phoneme or syllable of the target word, e.g., /fE/ for the item *fenêtre*/window.

Semantic paraphasias: Words corresponding to the category name or a semantic coordinate of the target word; e.g., *hibou*/owl for the item *lama*/lama.

normative means: 27/32 and 25.4/32; $SD = 2.2$ and 4.7) while it was the case for only one of the two easiest parts (DL: 24/32 and 23/32; normative means: 28.9/32 and 30.5/32; $SD = 2.4$ and 1.4). This pattern indicated that visuo-perceptual and structural processing was relatively spared in DL. Hence, her impaired performance in picture naming, in word-to-picture matching, and in the picture version of the semantic association task could not be ascribed to difficulties with the visual processing of picture stimuli.

Auditory and visual lexical processing. DL was presented an auditory lexical decision task composed of 120 items: 60 low-frequency words and 60 pseudowords that conformed to the French phonotactics. Of the pseudowords, 25 were made up by changing a single phoneme at the beginning, the middle, or the end of an existing word. The remaining 35 pseudowords were more distant from existing words. The words from which the pseudowords were created were matched for frequency and word length to the critical words. The items were presented in a random order and DL was asked to tell whether the stimulus was a word or not. DL's performance (112/120) was slightly below the normal range (controls' mean: 119.5; range = 117–120). Most of her errors consisted of rejecting words. DL was also presented a visual lexical decision task, which also consisted of 120 items; 60 words and 60 pseudowords. The set of words included 20 regular and 20 irregular words as well as 20 homophones of irregular words, matched for length and frequency. The pseudowords included 40 items matched for letter length to the 40 words (regular and irregular) and 20 pseudowords that were homophones of real words. DL's scores (117/120) were within the normal range (controls' mean: 117.5; range = 115–120).

Thus, on the whole, DL's lexical processing was spared for visual word stimuli, while for auditory word stimuli a very mild impairment could not be ruled out.

Semantic processing

Picture and word categorisation. DL was presented a categorisation task composed of four sets of 18 items. Two sets of 18 items had to be classified into three "distant" semantic categories: a first set of 18 items had to be classified into the categories of animals, implements, or clothing, and a second set of 18 items into the categories of transportation, musical instruments, and guns. The two other sets of 18 items had to be classified into three "close" semantic categories: hygiene, kitchen, or desk implements for one set; air, sea, or land transportation for the other. In each set, the 18 items were presented as picture, spoken, or written word stimuli in three separate sessions and in a random order. The names of the semantic categories were provided to the patient when needed.

As indicated in Table 5, DL's performance was good albeit not perfect for the classification into "distant" semantic categories, but her performance decreased for the classification into "close" semantic categories. Moreover, in that latter case, DL could not achieve the task without being provided with the name of the semantic categories. Given that the control participants performed both kinds of categorisation perfectly, quickly, and without any assistance, one can consider that DL was impaired in retrieving even superordinate semantic knowledge.

Word–picture verification task with living vs non-living things. This task was composed of 72 items, of which half (36) were living things (18 animals and 18 fruit and vegetables) and half nonliving things (18 implements and 18 means of transport). Living and nonliving items were matched for word frequency, concept familiarity, and visual complexity (see for details, Samson, Pillon, & de Wilde, 1998). DL was presented each pictured item (black-and-white drawing) simultaneously with a spoken word, and was asked to tell whether the word was the correct name for the depicted item. Each picture (e.g., of a donkey) was presented once with the correct word, once with a word that was a "close" semantic coordinate of the correct word (*horse*), and once with a word that was a "far" semantic coordinate (*hippopotamus*). An item was scored as correct when DL both accepted the correct word and rejected the two coordinates. DL's performance was severely below normal controls' performance for both living and nonliving entities (see Table 5). No effect of semantic domain (living vs nonliving) was found. DL's most common errors (85%) consisted in accepting a close coordinate of the target.

Synonym pointing task with abstract vs concrete verbs vs nouns. This task included 120 words of which 60 were nouns and 60 were verbs. Within each grammatical class, half of the items were abstract words, the other half concrete words. The words were matched for frequency across the four sets. DL was auditorily presented with each word (the cue) simultaneously with a pair of written words and asked to tell which of the written words had (approximately) the same meaning as the cue word. Each cue word (e.g., *coussin*/cushion) was presented once with a word pair composed of the target (i.e., a synonym: *oreiller*/pillow) and a semantic foil (*matelas*/mattress), and once with a pair of words composed of the same target and an unrelated foil (*barrage*/barrage). An item was scored as correct when DL rejected both the semantic and the unrelated foil. As displayed in Table 5, DL's performance was impaired for both nouns and verbs and for both concrete and abstract words.

Interim discussion

Thus far, the results of the case analysis revealed that DL's performance was impaired in all the tasks probing semantic knowledge without requiring a spoken output, except in spoken word classification into distant semantic categories. These results demonstrated that DL was still able to retrieve some general semantic information (category membership) about objects but was impaired in retrieving more specific semantic knowledge (which is required in word classification into close semantic categories, word-to-picture matching, word-picture verification, and synonym pointing). Moreover, the patient's performance in the tasks probing semantic knowledge was consistent across time and impaired whatever the stimulus modality (spoken or written word or picture) and the knowledge domain (living and nonliving things as well as concrete and abstract objects and actions). The results also showed that impaired performance in these tasks could not be ascribed to impairment of picture or word recognition processes, which were relatively spared in DL. All this was strong evidence for the existence of a semantic deficit, which was likely the main cause of her severe anomia.

However, the results revealed a very large discrepancy between DL's performance in naming and comprehension of the same items: she named only 2 items out of 80 of the *LEXIS*, while she scored 62/80 and 55/80 for the same items in the spoken and written version of the word-to-picture matching task, respectively. Such a large discrepancy between naming and comprehension was unlikely to be due exclusively to the naming task having higher semantic demands than the comprehension task. In a more demanding comprehension task, the word–picture verification task (see Breese & Hillis, 2004), DL performed at around 50%, which was still far from her floor performance in spoken naming. Therefore we put forward the hypothesis that DL had an additional deficit, located at some stage of the spoken word output system, which further impaired her spoken naming. The data analyses presented in the next section aimed at investigating this hypothesis.

Spoken output processing

Following current models of word production (Caramazza, 1997; Levelt, Roelofs, & Meyer, 1999), we assumed the following processing levels within the word production system:

1. The semantic level, at which the semantic features or the concept corresponding to the target word are represented and first activated during the process of word production.
2. The lexical level, at which two sub-levels are distinguished: one at which a modality-specific (Caramazza, 1997) or modality-neutral (Levelt et al., 1999) lexical unit is activated and selected on the basis of its meaning, and a second, the modality-specific word-form level, where the phonological (or orthographic) content of the lexical unit is retrieved and encoded.
3. At the post-lexical level, the word's phonological (or orthographic) content is temporarily held in memory (phonological or graphemic buffer) during its transfer to articulatory (or graphic) motor programs.

In the presence of a deficit located at the first processing level of the word production system, i.e., the semantic level, it is obviously difficult to formally assess the integrity of each of the subsequent processing levels. Furthermore, the most frequent naming errors made by DL were non-responses, which provided us no clue about the level at which they arose. Non-responses may result equally from a failure to activate information at the semantic, lexical, or post-lexical level. However, there were three features of DL's pattern of naming performance that suggested the existence of an additional deficit at the lexical processing level of the spoken naming system.

The first feature was the occasional phonological paraphasias and *conduites d'approche* amidst DL's spoken naming errors. It is reasonable to assume that, in this type of errors, the phonological content of the target word has been retrieved in part, which implies that both the target word's semantic features and the corresponding lexical unit have previously been accessed successfully. Accordingly, the failure must have arisen at either the word-form or the post-lexical processing level. In order to formally rule out the post-lexical processing level as the source of these phonological paraphasias and *conduites d'approche*, repetition of words and nonwords was further explored in DL. She was asked to repeat a set of 48 concrete words and 40 tri-syllabic nonwords. DL was 100% correct in repeating both the words and the nonwords, which allowed us to rule out damage to a post-lexical processing level (phonological buffer or/and articulatory patterns) as the source of her impaired performance in spoken naming and, in particular, of her phonological paraphasias and *conduites d'approche*. These errors thus likely arose at the lexical, word-form level, where the phonological content of a word has to be retrieved and encoded.

The second feature of DL's spoken naming performance further pointing to a deficit at a lexical level was that phonemic cueing was not effective at all in eliciting the target word (see above). One may assume that, in presence of a semantic deficit that nevertheless spared access to semantic category information, as was the case in DL, providing the initial phonemes of the target word may be sufficient to elicit the retrieval of that word, if the lexical processing levels themselves were not impaired. For instance, knowing only that the target item is an animal and its name starts with /'taɪ/ should help in finding /'taɪgər/, if lexical representations and processes were spared.

Finally, the third feature suggesting that a deficit at the lexical level also contributed to DL's impaired performance in spoken naming was revealed by the contrast between DL's performance in spoken and written naming. We reasoned that, because the semantic processing level is assumed to be shared by both modalities of naming (Caramazza, 1997; Levelt et al., 1999), and the spoken post-lexical level was spared in DL (see above), one should expect a similar pattern of performance in the spoken and written modalities if there was no additional deficit at a specific spoken (or written) word processing level. In contrast, in the condition of an additional deficit at a spoken word processing level, more errors should be observed in spoken in comparison to written naming when probed with the same set of items. To test this hypothesis we presented DL with a spoken and a written naming test comprising the same set of 48 pictures of objects. (Let us note that the target words were the same as those presented in the repetition task mentioned earlier.) It turned out that DL's level of performance was similar in spoken and written naming (1/48 and 9/48, respectively). However, her errors differed between both modalities. As in the *LEXIS* picture naming test (see above), DL produced a number of phonological paraphasias in spoken naming. Word-form errors were observed in written naming as well. Taking into consideration only the word-form errors that shared at least half of their phonemes or graphemes with the target (e.g., *assiette*/plate, named /asjɛRt/ instead of /asjɛt/; *chaise*/chair, written as CHAIDE), it appeared that there were more word-form errors, both in total and proportionally, in written than in spoken naming (14/39 errors, 36% vs 6/47 errors, 13%, respectively). That this type of erroneous responses occurred more often in written than spoken naming indicated that, more often in the written than in the spoken modality, the lexical unit corresponding to the target word as well as part of its form were successfully retrieved. Because this discrepancy could not be ascribed to the semantic nor the post-lexical level of the spoken word production system, it had to be located at the lexical level: either the lexical selection or the word-form encoding processes or both[3] more often completely failed in spoken than written naming. Thus, there was suggestive evidence that the lexical level within the spoken production system was more severely impaired than the corresponding level within the written production system and, hence, that damage to the lexical processing level within the spoken word production system contributed to DL's severely impaired performance in spoken naming.

Summary

The case analysis revealed that DL's performance was impaired in all the tasks where access to fine-grained semantic knowledge was required, whatever the modality of presentation of the stimuli and whether word production was involved or not, which is the hallmark of a loss of semantic knowledge. Moreover, the large discrepancy between DL's level of performance in naming and comprehension of the same items, as well as her pattern of errors in spoken and written naming, indicated the presence of an additional deficit at the lexical level of the spoken word production system. Finally, the case analysis revealed that the pre-semantic, whether visual or lexical, processing levels within the naming system were relatively spared in DL.

THERAPY STUDY

Overview

The therapy aimed at relearning semantic information about 16 previously known concrete entities each belonging to a distinct semantic category: trees, flowers, fruit, vegetables, birds, insects, mammals, molluscs, transport, tools, musical instruments, cosmetics, kitchen implements, office implements, fashion accessories, and sport. The patient was trained to link a number of relevant semantic attributes to each of the 16 target items, within the context of a learning task minimising the chance of producing an error. Further learning principles were applied:

1. Because semantic knowledge probably is acquired through multi-modal experiences with the environment (Simmons & Barsalou, 2003), the items' attributes

[3] This depends on the specific lexical processing model taken as reference. If we assume that the lexical selection level is modality neutral (Levelt et al., 1999) and, accordingly, shared by both modalities, then we must conclude that it was the word-form level that was more severely impaired within the spoken in comparison to the written production system. On the other hand, if we assume that the lexical selection level is modality specific (Caramazza, 1997), then we cannot specify, on the basis of the available evidence, whether the processing level that was more impaired in the spoken than the written system, was the lexical selection, the word-form, or both levels.

were presented to the patient in several modalities; that is, not only by their spoken and written names but also by pictures, pantomimes, sounds, and smell.

2. Assuming that concepts are formed by a generalisation process based on multiple exemplars of the same entity (Bonthoux, Berger, & Blaye, 2004; Simmons & Barsalou, 2003), the items that were manipulated during therapy were represented by several different exemplars (different photographs of the same item).
3. We assumed that categorising an object *X* as member of category A implies recognising the similarity of *X* to previous exemplars of category A as well as differentiating *X* from the exemplars of category B (Heit, 1994); hence, the properties of a given item were presented by *contrasting* them to those of a closely related item.

Method

Baseline evaluations

Materials. The material included 48 items divided into three lists (A, B, and C) of 16 items each. List A was composed of the 16 items to learn (“target” items), list B of 16 items that served as contrasting items during the training of list A (“contrast” items), and list C of 16 items never presented during therapy and that served as control items. The three lists were made with triplets of coordinate items, with each triplet drawn from a distinct semantic category. Lists A, B, and C were matched for mean concept familiarity, which was rated on a 5-point scale (1 = unfamiliar, 5 = very familiar) by 50 normal participants matched for age and education with DL. The mean rated familiarity was 3.70 for list A, 3.60 for list B, and 3.68 for list C, $F(2, 122) < 1$. The mean semantic proximity between the items of list A and list B, and between the items of list A and list C, was also controlled. Semantic proximity was rated on a 5-point scale (1 = few shared attributes; 5 = many shared attributes) by 30 normal participants matched for age and education with DL. The mean semantic proximity was 3.27 between list A and list B and 3.26 between list A and list C, $t(30) < 1$. The three lists of items are displayed in Appendix A.

Tasks. Semantic knowledge about the 48 items was probed in an attribute verification task and a spoken and written picture naming task.

- Attribute verification task. The spoken name of each 48 items was associated with a series of true and false semantic attributes. There were five to seven true and five to seven false semantic attributes per item (on average, six true and six false attributes per item). Thus, there were 288 true attribute–item and 288 false attribute–item associations, in total, 576 trials in this task.

The unequal number of attributes per item was a consequence of the selection procedure. Thus, the attributes were selected from a list provided by five normal participants matched with DL for age, education, and gender, who were asked to list what they considered the main, relevant, properties of each of the 48 items. Only the properties produced by at least three participants were kept for the task, which yielded a final list of five, six, or seven properties per item. Two types of attributes were distinguished: category membership (i.e., “animal” for the item *rabbit*) and non-category attributes like visual, other sensory (smell, taste, sound), functional, contextual, and encyclopaedic attributes. The non-category attributes were *distinctive* properties of the object, that is, properties that were true for one item ("eats carrots" for the item *rabbit*) and false for its coordinate ("eats carrots" for the item *mouse*). Because the selection of the attributes included in the task was based on the list of attributes the normal participants considered as the main, relevant, properties of a given item, the various kinds of non-category attributes (i.e., visual, other sensory, functional, contextual, and encyclopaedic) were not evenly distributed across the items (e.g., there was no sound attribute for the item *rabbit* although there was one for the item *guitar*). However, eventually, it turned out that the distribution of each type of non-category attributes was very similar across items, with the visual attributes being the most often occurring type.

The true and false trials were created as follows. The true attributes for one item were used as false attributes for one of the two remaining coordinate items of the triplet. For example, "eats carrots" was a true attribute for the item *rabbit* of the list A and "eats cheese" was a true attribute for its coordinate item *mouse* of the list B. Thus, "eats carrots" was used as a false attribute for the item *mouse* and "eats cheese" as a false attribute for the item *rabbit*. Moreover, as shown in this latter example, for every true attribute (e.g., "eats carrots" for the item *rabbit*), there was a false attribute (e.g., "eats cheese") that was related to the same kind of object features (e.g., "eats carrots" and "eats cheese" both expressed a property related to eating habit), thus forming 288 pairs of related true–false attributes in total. Examples of such pairs of related true–false attributes are provided in Table 7.

Each trial was presented in both the verbal and a nonverbal modality (see Appendix B for illustration). In the verbal modality, the item and one of its attributes were presented within a spoken interrogative sentence (e.g., *Le lapin mange-t-il généralement des carottes?*/Does the rabbit eat carrots?). In the nonverbal modality, the item was still identified by its spoken name but the attribute was displayed in another modality. Thus, visual attributes, as well as other kinds of

TABLE 7
Examples of pairs of related true and false attributes for the various types of attributes probed in the attribute verification task

Item	*Attribute type*	*Attribute status*	*Attribute tested*
Belt	Category	True	Accessory
	Non-category	False	Musical instrument
Bee	Visual (color)	True	Mostly yellow and black
		False	Mostly red and black
Lavender	Other sensory (smell)	True	Smell of a lavender
		False	Smell of a lily of the valley
Strawberry	Other sensory (taste)	True	Taste of a strawberry
		False	Taste of grapes
Guitar	Other sensory (sound)	True	Sound of a guitar
		False	Sound of a violin
Stapler	Functional	True	Used to attach
		False	Used to punch
Rabbit	Contextual	True	Lives in burrow
		False	Lives in trees
Swimming	Encyclopaedic	True	Mark Spitz
		False	Nadia Comaneci

attributes that were easily depicted by a picture, were displayed by a colour photograph. For example, for the functional attribute "eats carrots" of the item *rabbit*, the examiner showed a photograph depicting carrots and asked whether it was usually eaten by the rabbit (i.e., *Le lapin mange-t-il généralement ceci?*/Does the rabbit usually eat this?). As for the attributes that were not easily pictorially depicted, they were presented, depending on the kind of attribute probed, by a pantomime (e.g., the examiner performed the typical gestures associated with the use of a violin and asked whether the gestures corresponded to the *violin*), a sound (e.g., the examiner played a record of the typical sound of a guitar and asked whether that sound was from a *guitar*), or a smell (e.g., the examiner presented a perfume sample and asked whether it smelled like *lavender*). However, we must point out that 16 true and 16 false (related) attribute–item associations in each list could not be presented in the verbal modality (i.e., the true and false attributes related to the smell of *lavender*) and were presented in the nonverbal modality only. To allow us to compare the results obtained for the verbal and the nonverbal modality, the data obtained for these 32 trials were excluded for the analyses, so that, in total, the data set included the results obtained for 480 trials; that is, 240 pairs of related true and false attribute–item associations. The patient was instructed to say whether each attribute–item association was true or false. No feedback on the accuracy of the response was given to her. Given the stringent correction criteria applied (see later) and the large number of trials employed, the attribute verification task was administered only once.

- Spoken and written picture naming task. The patient had to name orally and in writing the photographs depicting the 48 items. No feedback was provided after the patient's response.

Ordering of the baseline evaluations. The baseline evaluations took place immediately before therapy, immediately after the completion of the therapy, and 1 year later. In each evaluation period, the naming task was administered prior to the attribute verification task. To minimise the potential effect of the repeated presentation of the items in both modalities, an ABBA design was applied for the naming task: DL was asked to name orally the first 24 items and then to write down the 24 next items. At the following session, the response modalities were counterbalanced. Likewise, the trials of the attribute verification task were presented following an ABBA design: the first half of trials were probed in the verbal modality and then the second half were probed in the nonverbal modality. At the following sessions, the modalities of testing were counterbalanced.

Therapeutic program

Materials. The therapy consisted in presenting a mean of six true attributes about each item of List A (target items) by contrasting them to those of the coordinate items of list B (contrast items). The item attributes were those tested in the baseline attribute verification task (i.e., category and non-category attributes). However, in the nonverbal presentation they were presented by distinct colour photographs from those used in the baseline task. Four different photographs (exemplars) of each item and each related attribute of list A and B were selected for therapy. The photographs of a given item differed as regards prototypicality (from highly to slightly prototypical). Attributes like category, utilisation, olfactory and auditory attributes were depicted either by a photograph (when it was possible to depict the property with a photograph) or by a pantomime, a perfume sample, or a sound (see details in Appendix C).

Therapy tasks. The learning protocol for the items of List A was subdivided into two phases:

- Phase 1: Presentation of all the semantic attributes of a given target item.

One green and one red sheet of paper were placed on the table in front of the patient. Then several photographs associated with each pair of target/contrast items were added separately: the therapist placed on the green sheet one photograph of the target item (the most prototypical) and one photograph for each related attribute to learn (mean of six). On the red sheet, the therapist placed one photograph of the contrast item (list B) and one photograph for each of its attributes contrasted with an attribute of the item from list A. In addition, the written and spoken names of each target item and of its related attributes were provided. The names of the items and attributes of the contrast list were *not* provided. The therapist spoke the name of each item and attribute of the target list three times and simultaneously showed its depiction (see Appendix D for illustration). All the photographs and names introduced during phase 1 (items of lists A and B and their attributes) remained visible during phase 2 in order to limit the production of errors by the patient.

- Phase 2. Picture matching with an error-reducing technique.

The green and the red sheet of paper remained on the table in phase 2. For each pair of target/contrast items, the patient was presented successively with seven sets of six photographs. The first set of photographs (phase 2, part 1) focused on the training of the target *items* while the next six sets of photographs (phase 2, part 2) focused more on the training of their related *attributes*. The first set of photographs included three new photographs (exemplars) of the target item and three new photographs (exemplars) of the contrast item (see illustration in Appendix E). All these photographs were presented in a random order and DL was asked to place them in the appropriate column: all the photographs related to the target item (list A) had to be placed in the green column and all the photographs related to the contrast item (list B) in the red one. The next six sets of photographs consisted of three different photographs depicting a semantic attribute of the target item and three photographs depicting a semantic attribute of the contrast item (see Appendix F). The photographs were presented in a random order and DL was asked to place them in the appropriate column (green if related to the target item and red if related to the contrast item). In order to limit the occurrence of errors, the picture classification task was achieved in four steps, by a regressive cueing strategy applied as follows:

1. Maximal cue: The therapist cued all the correct photographs of list A by presenting a green card and speaking the word "green" simultaneously with the three photographs DL had to put in the green column. Since the green card and the spoken word ('green') directly fitted with the colour of the column in which DL was supposed to place the photograph, erroneous responses were avoided. Furthermore, DL was told that all the exemplars related to the target item would be cued, and was advised to wait for each cue before matching.

2. Intermediate cue: Only two out of three correct photographs of list A remained cued with the green card and the spoken cue ‘‘green’’; the cues were omitted on the most prototypical photograph of the item in order to limit erroneous responses. DL had to match the remaining photographs on her own and was warned that no cue would be given for these exemplars.
3. Minimal cue: Only the less prototypical photograph of the target item remained cued by the therapist for matching; the remaining photographs were not cued and DL was asked to classify on her own.
4. No cue: DL was asked to perform the task on her own without any cue.

The learning protocol was adapted for attributes like category membership, utilisation gestures, olfactory and auditory attributes. The adaptations are detailed in Appendix C.

Timing. Once the patient performed accurately without cueing on the two learning phases for a given target item, she was presented with the next pair of target/contrast items and its related attributes. However, if any error occurred, the therapist corrected it and returned to the previous cueing step until the patient performed on her own without error. For example, if DL failed in the minimal cue step, she was presented with the intermediate cue step once again. If she performed this latter step without error, she was presented with the next steps (minimal cue and no cue). The criterion for the completion of the therapy was that DL had to succeed all tasks on her own on two distinct occasions for each target item. The semantic therapy was completed after eight learning sessions of 2 hours each and carried out in two consecutive weeks. During the first six sessions, each item of list A was trained once (in every task) and during the two last sessions, all the items were trained once again.

Empirical predictions

In the attribute verification task:

- Improvement in DL’s performance was expected for the semantic attributes of the items from list A, whether the attributes were probed verbally or nonverbally, since they were learned in both modalities during therapy. Improvement should be observed for both category-membership and non-category attributes, since both types were trained during therapy.
- Because both the category-membership and the non-category attributes of items of list B were contrasted during therapy with those of list A in the nonverbal modality, DL’s performance should improve for both kinds of attributes when probed nonverbally. Also, improvement was expected for the category-membership attributes probed in the verbal modality because the names of these attributes were provided during the training of the items from list A, which were coordinates of the items from list B and thus shared the category-membership attribute with the items from list B. However, we did not expect improvement for the non-category attributes probed verbally, because they were never presented in this modality during therapy. In sum, for the items of list B, improvement in DL’s performance was expected for (i) the category-membership attributes in both the verbal and nonverbal modalities and (ii) the non-category attributes in the nonverbal modality only.

- For the items of list C, improvement was expected for the category-membership attributes, both when probed verbally and nonverbally, since they were indirectly trained with the items of list A (lists A and C were made of coordinate items which thus shared category-membership). However, no improvement should be observed for the non-category attributes either probed verbally or nonverbally, since they were not trained or ever presented during therapy.

In the spoken and written naming task:

- Since we have assumed that DL's severely impaired spoken naming performance was mainly due to a loss of semantic knowledge, relearning such knowledge and especially distinctive (non-category) semantic attributes should improve her spoken naming for the items of lists A and B. However, DL probably also had damage to spoken word retrieval processes and the therapy did not target this deficit. Although the spoken names of the items of list A were provided during therapy, DL never had to name or even repeat them, which is a crucial condition to improve access to the spoken word form (Hillis & Caramazza, 1994; Howard, Patterson, Franklin, Orchard-Lisle, & Morton, 1988; Le Dorze, Boulay, Gaudreau, & Brassard, 1994). Therefore the benefits the therapy would have on semantic knowledge of the items of lists A and B could be partially or even totally obscured by DL's persistent damage to spoken word retrieval processes. Thus, at best limited improvement could be observed in spoken naming for the items of list A and, to a lesser extent, the items of list B (of which names were never provided during therapy). For the items of list C, no improvement should be observed in spoken naming at all, since neither their distinctive semantic attributes nor spoken names were trained or ever presented during therapy.
- Relearning semantic knowledge should also improve DL's written naming performance for the items of lists A and B, if semantic damage were the mere source of her written naming deficit. However, written word production was not fully investigated in DL's case analysis and we could not specify whether additional lexical or/and post-lexical damage contributed to her written naming deficit. Thus no formal prediction could be drawn as for the therapy effects on DL's performance in the written naming task. Nevertheless, let us note that, if the lexical or/and post-lexical written-specific processes were impaired in DL, only little if any improvement in written naming would follow from therapy, since DL never had to copy or write down the names of the items (whatever the list) during the therapy tasks.

Results

Attribute verification task

Scoring. DL was given credit for a correct response if she answered accurately on both the true and the false trial of a pair of related true–false attributes, e.g., if she both accepted the true attribute "carrots" *and* rejected the related false attribute "cheese" for the item *rabbit*. Since there were 240 true and 240 false trials—that is, 240 pairs of related true–false trials—the total maximum score was 240 and the maximum score per list was 80 (chance score = 25%).

Pre-therapy assessment. The results are displayed in Table 8 and Figure 2. The data analyses were first performed with the category and the non-category attributes considered together (Figure 2a) and then, separately, for the category (Figure 2b) and the non-category (Figure 2c) attributes.

When the category and the non-category attributes were considered together, the data analyses revealed that DL's level of performance before therapy was similar for the target (A), the contrast (B), and the control list (C). Paired comparisons revealed no significant difference in DL's performance between the lists in neither modality of testing (verbal: $0.02 < \chi^2(1) < 1.6$, all $ps > .1$; nonverbal: $0.2 < \chi^2(1) < 2.6$, all $ps > .1$). Considering the category attributes only, the analysis revealed that DL's performance did not significantly differ across the three lists, whatever the modality of testing ($\chi^2(1) < 1$ for all the comparisons in both modalities). As for the non-category attributes, DL's performance in the verbal modality of testing was not significantly different across the three lists ($0.3 < \chi^2(1) < 2$, all $ps > .1$). However, in the nonverbal modality of testing, her performance was significantly better on the control list (C) than on the target (A) and the contrast (B) lists ($\chi^2(1) = 3.8$, $p = .05$ for both the A vs C and B vs C comparisons). It thus appeared that the three lists of items were not perfectly matched in difficulty. However, it is important to note that any improvement observed on the target or/and the contrast lists after therapy could not be ascribed to these lists being easier for DL than the control list, since actually it was the control list that was easier for the patient, in particular for the non-category attributes in the nonverbal modality of testing.

Post-therapy assessment. Since the three lists of items were not perfectly matched in difficulty before therapy, the therapy effects were first measured by comparing

TABLE 8
DL's number (and percentage) of correct responses in the attribute verification task according to the type of attributes (category vs. non-category), the modality of testing (verbal vs. nonverbal), and the list of items (A = target items; B = contrast items; C = control items) at the pre-therapy, post-therapy, and follow-up assessment.

		Verbal modality			*Nonverbal modality*		
		Pre	*Post*	*Follow-up*	*Pre*	*Post*	*Follow-up*
List A	Category ($N = 16$)	13 (81%)	16 (100%)**	13 (81%)	14 (87%)	16 (100%)**	16 (100%)**
	Non-category ($N = 64$)	27 (42%)	41 (64%)**	34 (53%)	30 (47%)	48 (75%)**	48 (75%)**
	Total ($N = 80$)	40 (50%)	57 (71%)**	47 (59%)	44 (55%)	64 (80%)**	64 (80%)**
List B	Category ($N = 16$)	11 (69%)	16 (100%)**	13 (81%)	11 (69%)	16 (100%)**	15 (94%)**
	Non-category ($N = 64$)	22 (34%)	32 (50%)°	31 (48%)	30 (47%)	38 (59%)	42 (66%)*
	Total ($N = 80$)	33 (41%)	48 (60%)*	44 (55%)°	41 (51%)	54 (67%)*	57 (71%)**
List C	Category ($N = 16$)	11 (69%)	16 (100%)**	14 (87%)	10 (62%)	15 (94%)**	14 (87%)
	Non-category ($N = 64$)	30 (47%)	41 (64%)°	33 (51%)	41 (64%)	41 (64%)	44 (69%)
	Total ($N = 80$)	41 (51%)	57 (71%)*	47 (59%)	51 (64%)	56 (70%)	58 (72%)

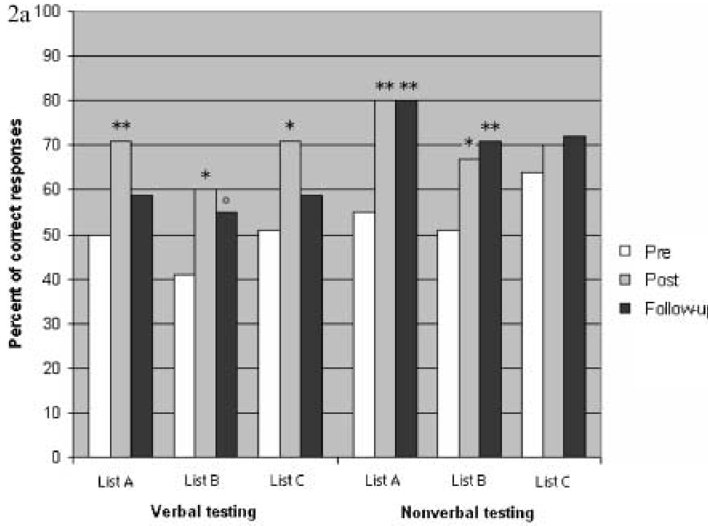
** = highly significant therapy effect ($p < .01$) or ceiling performance
* = significant therapy effect ($.01 < p < .05$)
° = near significant therapy effect ($.05 < p < .1$).

DL's performance before and after therapy on each list separately. Then, in order to test for possible differences in the therapy effects between the three lists, we compared the number of items that, in each list, were failed at pre-therapy and then succeeded post-therapy, succeeded at pre- and failed at post-therapy, succeeded both pre- and post-therapy, or failed both pre- and post-therapy.

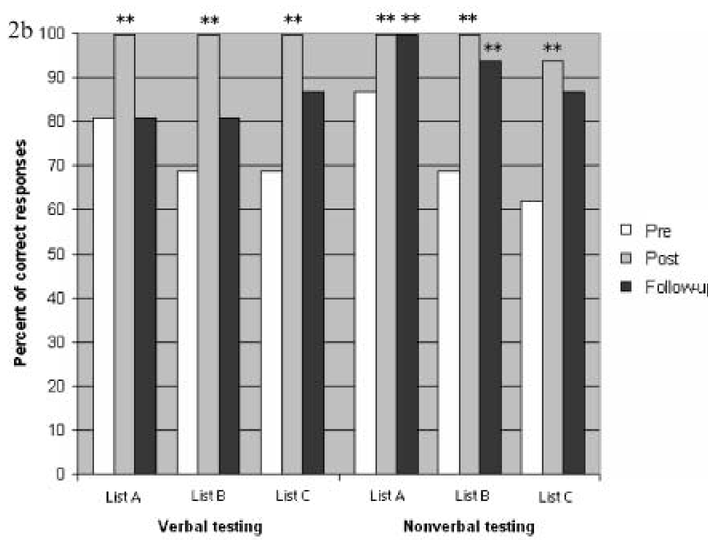
When the category and the non-category attributes were considered together, the data analyses revealed a significant improvement in DL's performance for the attributes of list A, both in the verbal (McNemar's test, $p < .01$) and the nonverbal (McNemar's test, $\chi^2 = 9$, $p < .01$) modality as well as for the attributes of list B, in both modalities too (verbal: McNemar's test, $\chi^2 = 5$, $p < .05$; nonverbal: McNemar's test, $\chi^2 = 4.6$, $p < .05$). DL's performance for the attributes of list C significantly improved in the verbal modality of testing only (verbal: McNemar's test, $\chi^2 = 5.9$, $p < .05$; nonverbal: McNemar's test, $\chi^2 < 1$). The test comparing the therapy effects between the lists revealed no significant difference, neither in the verbal ($\chi^2(6) = 10.5$, $p > .1$) nor the nonverbal modality ($\chi^2(6) = 10.1$, $p > .1$), which indicated that DL's performance similarly improved on the three lists if the category and the non-category attributes are not distinguished in the analyses.

When the category and the non-category attributes were analysed separately, the results revealed that DL's performance on list A for the category attributes reached ceiling (no error) at the end of the therapy in both modalities, and that her performance for the non-category attributes significantly improved in both modalities (verbal: McNemar's test, $p < .01$; nonverbal: McNemar's test, $\chi^2 = 7.6$, $p < .01$). On list B, her performance for the category attributes also reached ceiling after therapy in both the verbal and the nonverbal modality of testing. Also, the results showed a trend, albeit non-significant, towards an improvement on the non-category attributes in both modalities but especially in the verbal one (verbal: McNemar's test, $\chi^2 = 2.9$, $p = .09$; nonverbal: McNemar's test, $\chi^2 = 1.8$, $p = .17$). On list C, DL's performance for the category attributes also reached ceiling after therapy in both modalities. For the non-category attributes, no significant difference was observed between pre- and post-therapy performance, although there was a trend for better performance after therapy in the verbal modality (verbal: McNemar's test, $\chi^2 = 3$, $p = .08$; nonverbal: McNemar's test, $p > .1$). The analyses comparing the therapy effects between the three lists revealed no significant difference between the lists as far as category attributes were concerned (verbal: $\chi^2(4) = 3$, $p > .1$; nonverbal, category: $\chi^2(4) = 4.2$, $p > .1$). As for the non-category attributes, no significant difference appeared between the lists in the verbal modality ($\chi^2(6) = 9.9$, $p > .1$) but, in the nonverbal modality, the amount of the therapy effects significantly differed between the lists ($\chi^2(6) = 15$, $p < .05$). Paired comparisons indicated a significantly larger improvement on list A in comparison with lists B ($\chi^2(3) = 8$, $p < .05$) and C ($\chi^2(3) = 9.7$, $p < .05$), whereas the improvement did not significantly differ between lists B and C ($\chi^2(3) = 3.8$, $p > .1$).

Although the improvement in DL's performance for the non-category attributes of lists B and C in the verbal modality did not reach significance, the fact that a similar trend was observed in both lists B and C for the same kind of attributes (i.e., non-category attributes) when probed in the same modality (i.e., verbal) is puzzling and needs some clarification, especially because such a trend was not expected. We entertained the hypothesis that the reason why DL's performance tended to improve on the non-category attributes of the lists B and C probed in the verbal modality was that she had relearned during therapy the meaning of the words used to describe

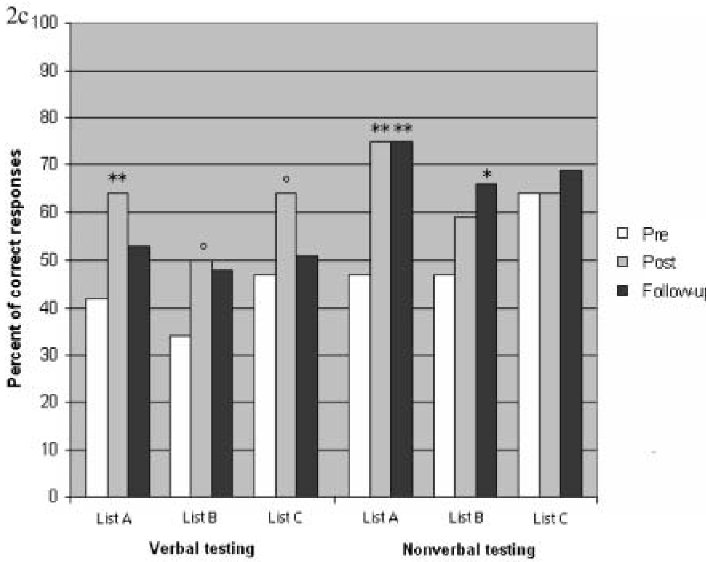


** = highly significant therapy effect ($p < .01$) or ceiling performance
* = significant therapy effect ($.01 < p < .05$)
° = near significant therapy effect ($.05 < p < .1$).



** = highly significant therapy effect ($p < .01$) or ceiling performance
* = significant therapy effect ($.01 < p < .05$)
° = near significant therapy effect ($.05 < p < .1$).

Figure 2 (above and opposite). DL's percent of correct responses in the attribute verification task according to the modality of testing (verbal vs. nonverbal) and the list of items (A = target items; B = contrast items; C = control items) at the pre-therapy, post-therapy, and follow-up assessment for the category and non-category attributes considered together (Figure 2a), separately for the category (Figure 2b) and the non-category (Figure 2c) attributes.



** = highly significant therapy effect ($p < .01$) or ceiling performance
* = significant therapy effect ($.01 < p < .05$)
° = near significant therapy effect ($.05 < p < .1$).

some of these semantic attributes. Thus, before the therapy, DL would have had spared knowledge for a number of the semantic properties of the items of lists B and C but had difficulty in *understanding the words* used to depict them, because these words were of relatively low frequency. It is the comprehension of these words that would have been improved by the therapy. At first sight, it may seem unlikely that DL had relearned the meaning of the words depicting some non-category attributes of lists B and C because none of these attributes was presented verbally during therapy. However, we propose that such a learning has taken place only for a subset of the non-category attributes of lists B and C, those whose verbal depiction shared words with the verbal depiction of the attributes of their coordinate items of the list A, which were trained both verbally and nonverbally during the therapy task.

Let us specify here that, in the verbal version of the attribute verification task used as baseline, it often happened that a non-category attribute of an item of the lists B or C was depicted with a phrase comprising a content word that also entered the verbal depiction of a non-category attribute of an item of the list A, which was *trained* both in the verbal and the nonverbal modality. It is the meaning of these shared words that DL could have relearned. Thus, for example, during the therapy, the item from the list A *weeping willow* was trained with a photograph *and* the corresponding phrase depicting its visual attribute "*a de fines* feuilles *allongées*"/has fine elongated *leaves*". During the therapy, its coordinate item from the list B *birch* was presented with only a photograph (not a phrase) depicting its visual attribute "*a de petites* feuilles *dentées*"/has small dentate *leaves*" but, in the attribute verification task, *birch* was probed verbally with the true sentence "*A-t-il des petites* feuilles *dentées?*"/Does it have small dentate *leaves*" and the false sentence "*A-t-il des* feuilles *lobées?*"/Does it have lobed elongated *leaves*" (which was true for the item *oak* of list C). Thus, DL may have relearned the meaning of the word *leaves* during the training of the attribute "fine elongated *leaves*" of the item *weeping willow* of list A and, provided she still knew this particular property of the birch before the therapy, she could then answer accurately to both the true and the false sentences probing knowledge of the birch in the baseline task.

To test this hypothesis, we re-analysed DL's responses in the attribute verification task for the non-category attributes of the lists B and C by considering separately each trial, true or false, and giving credit for a correct/incorrect response on each single trial. In that way, the total maximum score was 480 and the maximum score per list was 160. Then we counted the number of DL's correct responses across the three following type of trials: (1) False sentences that depicted the true attributes of list A; (2) True or false sentences that shared words with the sentences depicting the true attributes of items from list A; (3) True or false sentences that did not share words with the sentences depicting the true attributes of items from list A. The results are displayed in Table 9. The data analyses revealed that, for list B, DL's performance significantly improved for the sentences sharing words with those of the list A (McNemar's test, $p < .05$), but not for both the other kinds of sentences (McNemar's tests, both ps $> .1$). The same results were obtained for list C: the sentences sharing words with those of list A led to a significant improvement after the therapy (McNemar's test, $\chi^2 = 6.2$, $p < .05$) whereas both the other kinds of sentences did not (McNemar's tests, both ps $> .1$). In sum, the above analyses strongly suggested that DL's better performance after therapy for the non-category attributes of lists B and C when tested verbally was likely based on her relearning the meaning of the words used to verbally depict some of these attributes. However, as

TABLE 9

Number and percentage of trials DL succeeded in the attribute verification task for the non-category attributes of the items of the lists B and C probed in the verbal modality and according to whether the trial depicted a true attribute of an item from the list A, or shared or did not share words with the sentences depicting the true attributes of items from the list A

	List B (N = 128)		
Type of Trials	*Pre-therapy*	*Post-therapy*	*Follow-up*
False trials depicting a true attribute of an item from the list A ($N = 32$)	18 (56%)	17 (53%)	25** (78%)
True and false sentences that shared words with the trials depicting the true attributes of the items from the list A ($N = 39$)	22 (56%)	32* (82%)	26 (67%)
True and false trials that did not share words with the sentences depicting the true attributes of the items from the list A ($N = 57$)	38 (67%)	43 (75%)	41 (72%)
	List C (N = 128)		
False trials depicting a true attribute of an item from the list A ($N = 32$)	14 (44%)	21 (66%)	25° (78%)
True and false trials that shared words with the sentences depicting the attributes of the items from the list A ($N = 41$)	27 (66%)	37* (90%)	29 (71%)
True and false trials that did not share words with the sentences depicting the attributes of the items from the list A ($N = 55$)	42 (76%)	46 (84%)	42 (76%)

** = highly significant therapy effect ($p < 0.01$)
* = significant therapy effect ($0.01 < p < 0.05$)
° = near significant therapy effect ($0.05 < p < 0.1$).

we have already pointed out, such a relearning could have taken place only if DL had spared semantic knowledge of the item properties themselves before the therapy. Therefore, if this account is correct, we should observe that the non-category attributes on which DL's performance improved at post-therapy when probed verbally were already succeeded in at pre-therapy when probed nonverbally. Such a trend was indeed observed: 71% of the non-category attributes of lists B and C on which DL's performance improved after therapy when probed verbally were already succeeded in before therapy when probed nonverbally.

Follow-up assessment. One year after the completion of the therapy, DL's performance on list A in the verbal modality did not significantly differ from her pre-therapy performance (McNemar's test, $\chi^2 = 1$, $p > .1$). However, in the nonverbal modality, her performance was still significantly better than her pre-therapy performance (McNemar's test, $\chi^2 = 9.5$, $p < .01$). Likewise, on list B, DL's performance at the follow-up assessment was not significantly different from her pre-therapy performance in the verbal modality (McNemar's test, $\chi^2 = 3.2$, $p = .07$) whereas her performance in the nonverbal modality was still significantly better than pre-therapy (McNemar's test, $\chi^2 = 7$, $p < .01$). On list C, DL's performance at follow-up did not significantly differ from her pre-therapy performance in either the verbal (McNemar's test, $\chi^2 < 1$) or the nonverbal modality (McNemar's test, $p > .1$). The analyses comparing the therapy effects across the three lists revealed no significant difference in any modality (verbal: $\chi^2(6) = 1.7$, $p > .1$; nonverbal: $\chi^2(6) = 8$, $p > .1$).

Considering the category and the non-category attributes separately, the analyses revealed that, on list A, DL's performance at follow-up for the category attributes probed in the verbal modality did not differ from her performance at pre-therapy (McNemar's test, $p > .1$) whereas her performance for the category attributes probed in the nonverbal modality remained at the ceiling level reached post-therapy. Likewise, for the non-category attributes, the analyses revealed a significant difference between the pre-therapy and the follow-up performance in the nonverbal modality only (verbal: McNemar's test, $\chi^2 = 1.1$, $p > .1$; nonverbal: McNemar's test, $\chi^2 = 8$, $p < .01$). On list B, the pattern of results was identical to the one observed on list A: DL's performance for both the category and the non-category attributes did not significantly differ between the follow-up and the pre-therapy assessment when probed in the verbal modality (category: McNemar's test, $p > .1$; non-category: McNemar's test, $\chi^2 = 2.4$, $p > .1$) whereas, when probed in the nonverbal modality, the performance for both kinds of attributes significantly improved at the follow-up in comparison to pre-therapy (category: ceiling; non-category: McNemar's test, $\chi^2 = 4.3$, $p < .05$). On list C, DL's performance at follow-up did not significantly differ from her pre-therapy performance in any modality, for the category attributes (McNemar's test, $p > .01$ in both modalities) as well as for the non-category attributes (verbal: McNemar's test, $\chi^2 = 1.2$, $p > .1$; nonverbal: McNemar's test, $p > .1$). Let us add that the significant improvement shown at the post-therapy assessment for a subset of non-category attributes of lists B and C (those where the depiction shared words with the sentences depicting the true attributes of the items of list A), when probed in the verbal modality, did not maintain at the follow-up assessment. Thus, there was no significant difference between DL's pre-therapy and follow-up performance for this subset of non-category attributes probed in the verbal modality (McNemar's test, all ps $> .1$). Finally, the comparison of the long-lasting therapy effects across the three lists revealed no significant difference between the lists for the category attributes probed in any modality ($2.3 < \chi^2(6) < 5.4$, $p > .1$), and for the non-category attributes probed in the verbal modality (χ^2 (6) = 2.9, $p > .1$). On the other hand, the analyses revealed a significantly different improvement between the lists for the non-category attributes probed nonverbally: $\chi^2(6) = 12.6$, $p = .05$. Paired comparisons indicated that this difference was due to a significantly larger improvement on the list A in comparison to the list C ($\chi^2(3) = 10.8$, $p = .01$), while no significant difference emerged between lists A and B and between lists B and C ($3.4 < \chi^2(3) < 5$, $p > .1$).

To summarise, the results of the attribute verification task indicated the following changes:

1. On the target list (list A), DL's performance showed a significant improvement after therapy for both the category and the non-category attributes whether probed verbally or nonverbally. One year after the therapy, the significant therapy effects maintained for both kinds of attributes, although in the nonverbal modality of testing only.
2. On the control list (list C), DL's performance improved at post-therapy for the category attributes, both in the verbal and the nonverbal modality. However, these effects did not maintain 1 year after the therapy. The non-category attributes showed no significant improvement in any modality of testing, except for a subset of them: those whose verbal depiction shared words with the verbal depiction of attributes of the target list, which showed a significant improvement at post-therapy when probed verbally. However, here again, this positive therapy effect did not maintain 1 year later.
3. The results of the contrast list (list B) are less clear-cut and, in some sense, intermediate between those of the target and the control list. First, DL's performance significantly improved for the category attributes, when probed in both modalities, and these therapy effects maintained 1 year after the therapy when probed nonverbally–a pattern that was exactly like the one observed on the target list. Second, her performance improved, albeit non-significantly, for the non-category attributes when tested in both modalities and these trends maintained at the follow-up only when probed nonverbally—thus, here, the positive changes were similar but less sensible than the ones observed on the target list. Furthermore, as on the control list, the improvements observed for the non-category attributes probed verbally were likely confined to a subset of them, those whose verbal depiction shared words with the verbal depiction of attributes of the target list.

Furthermore, the magnitude of both the immediate and the long-lasting therapy effects was similar across the three lists as far as the category attributes were concerned, in the verbal as well as in the nonverbal modality of testing. Similar immediate and long-lasting therapy effects were also observed across the three lists for the non-category attributes probed in the verbal modality. The critical difference between the three lists concerned the non-category attributes probed in the nonverbal modality, which incurred significantly larger positive therapy effects in the target list than in the contrast and the control list, both at the post-therapy and the follow-up assessment.

Spoken and written naming task. DL's performance in the spoken naming task was still at floor at the end of the therapy (see Table 10). At that time, the patient

TABLE 10
Distribution of DL's responses in the spoken and the written picture naming task according to the list of items (A = target items; B = contrast items; C = control items) at the pre-therapy, post-therapy and follow-up assessment.

		Spoken naming			*Written naming*		
		Pre-therapy	*Post-therapy*	*Follow-up*	*Pre-therapy*	*Post-therapy*	*Follow-up*
LIST A	Non-responses	6	7	4	6	2	8
	Circumlocutions	2	0	6	0	0	0
	Neologisms	2	2	2	1	8	4
	Semantic paraphasias	2	1	0	1	1	1
	Phonological/literal paraphasias	2	1	2	3	4	3
	Verbal paraphasias	1	0	1	1	0	0
	Mixed paraphasias	0	0	1	2	0	0
	Ambiguous	0	3	0	2	0	0
	Correct responses	1	2	2	0	1	0
LIST B	Non-responses	4	7	2	7	3	6
	Circumlocutions	6	1	6	0	0	0
	Neologisms	2	2	5	3	3	3
	Semantic paraphasias	2	0	1	1	1	1
	Phonological/literal paraphasias	1	4	0	2	6	2
	Verbal paraphasias	1	0	1	0	0	0
	Mixed paraphasias	0	1	1	2	0	2
	Ambiguous	0	1	1	1	3	2
	Correct responses	0	0	0	0	0	0
LIST C	Non responses	6	5	2	7	1	6
	Circumlocutions	4	2	5	0	0	0
	Neologisms	1	1	1	1	2	1
	Semantic paraphasias	1	2	2	0	0	2
	Phonological/literal paraphasias	2	3	1	3	4	7
	Verbal paraphasias	0	0	2	0	0	0
	Mixed paraphasias	2	2	2	4	5	0
	Ambiguous	0	1	1	0	1	0
	Correct responses	0	0	2	1	3	0

produced only two correct responses. The nature and distribution of her errors did not show any significant change either. Errors mostly consisted of non-responses (mean of 6.3 per list), phonological paraphasias (mean of 2.6 per list), and neologisms (mean of 1.6 per list). Likewise, no significant change was observed in the written naming task whether as regards response accuracy or the distribution of error types. DL produced a single correct response after the therapy and the majority of her errors were literal paraphasias (mean of 4.6 per list), neologisms (mean of 4.3 per list), and non-responses (mean of 2 per list).

DISCUSSION

The aim of this study was to determine whether using an errorless learning method in a semantic therapy would prove effective for a patient presenting with both a semantic deficit and mild amnesia. During therapy, the patient was trained to associate a number of semantic attributes to 16 items. After eight therapy sessions, the patient's performance significantly improved in an attribute verification task probing semantic knowledge for these items and, to a lesser extent, also for semantically coordinate items. On the other hand, no improvement was observed in a spoken and written picture naming task, a result that was likely due to the patient having additional damage to the spoken and written word output processes and the therapy not having been designed to rehabilitate these processes.

In the attribute verification task we found that, after the therapy, the patient's performance was more accurate on the target items (list A) for both category-membership and more specific (non-category) attributes, whether these attributes were probed in the verbal or the nonverbal modality. Moreover, as was expected, knowledge of the items that were semantic coordinates of the target items—that is, the contrast (list B) and the control (list C) items—also improved, whatever the modality of testing, as far as category-membership attributes were concerned. It also appeared that further to category membership, other features shared by the items of lists A, B, and C caused positive learning transfers from list A to lists B and C. Thus, we found that DL's performance after therapy improved for some non-category attributes of lists B and C probed in the verbal modality, even though these attributes had not been trained in this modality in the case of list B and not trained at all in the case of list C. We proposed that this positive transfer occurred because the wording of these non-category attributes of the items of lists B and C included words that also entered the verbal depiction of the attributes of the items of list A. During the therapy task, the understanding of the words used to describe the semantic attributes of the items of list A was trained incidentally, because these attributes were provided both through the verbal and nonverbal modalities (photographs, pantomime, etc.). Hence, DL could also improve her understanding of the sentences used to probe attribute knowledge for the items of the lists B and C. In keeping with this account, we found that most of the non-category attributes of lists B and C on which DL's performance improved in the verbal testing were already succeeded in at the pre-therapy assessment when probed nonverbally—which strongly suggests that, in these cases, what had been learned concerned lexical meaning rather than semantic knowledge per se.

Using both the verbal and the nonverbal modality for training the semantic attributes during therapy may have other, more important positive effects. Thus, the results indicated that the patient succeeded in learning specific (non-category) attributes for the items of list A, and, to a lesser extent, specific attributes for the items of list B. During therapy, the attributes of the items of both lists A and B were trained, except that only the items and attributes of list A were trained in both the verbal and nonverbal modalities. The items and attributes of list B were trained only in the nonverbal modality. This suggests that the verbal presentation of the semantic attributes may be helpful (albeit not sufficient) to acquire novel semantic knowledge. However, the follow-up assessment showed that the learning effects observed for list A and, to a lesser extent, list B, persisted at 1 year post-therapy only when semantic attribute knowledge was probed in the nonverbal modality. This differential pattern of long-term effects according to the modality of testing suggests that knowledge about how a given semantic property is verbally described should be distinguished from knowledge of the semantic property itself, even if the former can help in learning the latter. Knowledge of how a property is described may necessitate rehearsal to be maintained over time, perhaps because the words used to express semantic knowledge are rather low frequency.

Whatever the role of the verbal presentation of the semantic attributes on semantic learning and the status of this kind of verbal knowledge, there is little doubt that the significant improvement observed for the items of list A reflects re-acquisition of *semantic* knowledge. First, improvement was present in both the verbal and the nonverbal modality. Second, the improvement in the nonverbal modality could not be ascribed to the learning of mere associations between a specific visual item and other specific visual depictions of the semantic properties, since all the photographs that were used in the baseline task were distinct from those used in the therapy task. The same holds for the re-acquisition of the category attributes of the items of the three lists. Improvement was observed in both the verbal and the nonverbal modality even though the photographs depicting these attributes were different in the therapy and the baseline task.

The discrepancy between the lack of change (neither quantitative nor qualitative) at the end of the therapy in the spoken naming task and the significant improvement in the non-production task (the attribute verification task) confirms the hypothesis that DL had an associated deficit in the selection of the lexical items or/and the retrieval of their phonological content. Even if semantic relearning was *necessary* to improve spoken naming, it proved to be *insufficient* because of DL's additional spoken word retrieval deficit. Moreover, the lack of quantitative or qualitative improvement in the written naming task suggests an associated deficit within the written word production system as well, which could not be ruled out on the sole basis of the pre-therapy evaluation. The semantic deficit could not be the single source of DL's written naming deficit, because if it was, semantic improvement should have been accompanied by changes in the number of correct responses, which was not the case.

The design of the present therapy had a number of limitations, however. First, it lacked additional control conditions, that is, control items that were not coordinate with the target items and control tasks not involving semantic knowledge but nevertheless impaired in DL (e.g., nonword reading). Thus, the therapy specificity could not be formally demonstrated either as regards the items (every item list showed some degree of improvement) or the cognitive processing component involved (i.e., semantic processing). However, the general pattern of the results makes it very unlikely that learning was unspecific in DL. Thus, for example, only knowledge of *category* attributes significantly improved in the three lists, which in fact points to a semantic factor underlying learning, and knowledge of the specific (non-category) attributes significantly improved and maintained for the items of the trained list (A) only, which clearly reflected the therapy specificity as regards item knowledge.

Second, the design lacked an evaluation of the therapy effects in everyday life. We nevertheless noticed that DL produced pantomimes much more often, in particular gestures referring to relevant features of an item (e.g., the typical gestures associated with a violin), during the post-therapy baseline naming task than at the pre-therapy assessment. This suggested that the therapy prompted her to use supplementary means of communication, which, we may hope, she will also use to communicate in her daily life.

Third, and more importantly from a theoretical point of view, no contrast was designed in the present study between errorless and errorful learning methods. We therefore cannot ascertain that this particular feature of the therapy task was indeed responsible for the success of the therapy. We cannot specify either the respective role of the other features of the learning task—that is, multi-modal, multi-exemplar, and contrastive stimulation—which were never included in previous therapy studies, to the best of our knowledge. Our positive results suggest these issues should be addressed in further specifically designed studies.

In conclusion, notwithstanding the limitations of the therapy design, and even though the number of trained concepts was very limited, the results clearly showed that a patient with a chronic and resistant semantic deficit associated with anterograde amnesia was able to re-acquire semantic knowledge after a therapy of very short duration. This is an encouraging finding that challenges the pessimistic conclusion of Sartori et al. (1994), drawn from their semantic therapy study with two HSE patients and according to which re-acquiring semantic knowledge is not possible in the condition of anterograde amnesia.[4] Furthermore, this therapy study provides evidence relevant to the issue of the functional relationships between episodic and semantic memory (Squire & Zola, 1998; Tulving & Markowitsch, 1998, 2001). Thus, it demonstrated that acquisition of novel semantic knowledge is possible even when episodic memory is impaired, which is not compatible with Squire and Zola's (1998) theory assuming that the acquisition of semantic knowledge *depends on* the integrity of episodic memory. The theory of Tulving and Markowitsch (1998, 2001), which assumes a partial independence between both components of declarative memory, could more easily account for the results of this study.

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[4] One might object that the positive outcome of the present therapy study was due to our patient suffering from a milder episodic memory deficit than those of Sartori et al. (1994). Unfortunately, we are unable to address this issue because the memory tests used in Sartori et al.'s study and in ours were different and do not allow us to compare reliably the episodic memory performance of their patients with that of DL.

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APPENDIX A

List of the target items (list A), the contrast items (list B) and the control items (list C).

	List A	*List B*	*List C*
1	*Saule pleureur* (weeping willow)	*Bouleau* (birch)	*Chêne* (oak)
2	*Lavande* (lavender)	Muguet (lily of the valley)	*Coquelicot* (poppy)
3	*Fraise* (strawberry)	*Prune* (plum)	*Raisins* (grapes)
4	*Poivron* (red pepper)	*Champignon* (mushroom)	*Radis* (radish)
5	*Chouette* (owl)	*Canard* (duck)	*Mouette* (gull)
6	*Abeille* (bee)	*Coccinelle* (ladybird)	*Papillon* (butterfly)
7	*Lapin* (rabbit)	*Souris* (mouse)	*Ecureuil* (squirrel)
8	*Huître* (oyster)	*Escargot* (snail)	*Moule* (mussel)
9	*Tram* (tramway)	*Métro* (underground)	*Taxi* (taxi)
10	*Bêche* (spade)	*Râteau* (rake)	*Sécateur* (secateurs)
11	*Ceinture* (belt)	*Foulard* (scarf)	*Gant* (glove)
12	*Tire-bouchon* (corkscrew)	*Ouvre-boîte* (tin-opener)	*Décapsuleur* (bottle-opener)
13	*Agrafeuse* (stapler)	*Taille-crayon* (sharpener)	*Perforatrice* (drilling)
14	*Guitare* (guitar)	*Violon* (violin)	*Piano* (piano)
15	*Vernis à ongles* (nail varnish)	*Rouge à lèvres* (lipstick)	*Fond de teint* (foundation cream)
16	*Gymnastique* (gymnastics)	*Natation* (swimming)	*Tennis* (tennis)

APPENDIX B

Illustration of the design of the attribute verification task used for baseline, for one pair of true-false attribute-item associations and two coordinate items (*lapin*/rabbit and *souris*/mouse)

Item tested	*Pair of attributes tested*	*Attribute status*	*Verbal testing*	*Nonverbal testing*
lapin (rabbit)	*mange des carottes* (eats carrots)	true	*Le lapin mange-t-il généralement des carottes?* [Does the rabbit usually eat carrots?]	*Le lapin mange-t-il généralement ceci?* [Does the rabbit usually eat this?] 
lapin (rabbit)	*mange du fromage* (eats cheese)	false	*Le lapin mange-t-il généralement du fromage?* [Does the rabbit usually eat cheese?]	*Le lapin mange-t-il généralement ceci?* [Does the rabbit usually eat this?] 
souris (mouse)	*mange du fromage* (eats cheese)	true	*La souris mange-t-elle généralement du fromage*? [Does the mouse usually eat cheese?]	*La souris mange-t-elle généralement ceci?* [Does the mouse usually eat this?] 
souris (mouse)	*mange des carottes* (eats carrots)	false	*La souris mange-t-elle généralement des carottes?* [Does the mouse usually eat carotts?]	*La souris mange-t-elle généralement ceci?* [Does the mouse usually eat this?] 

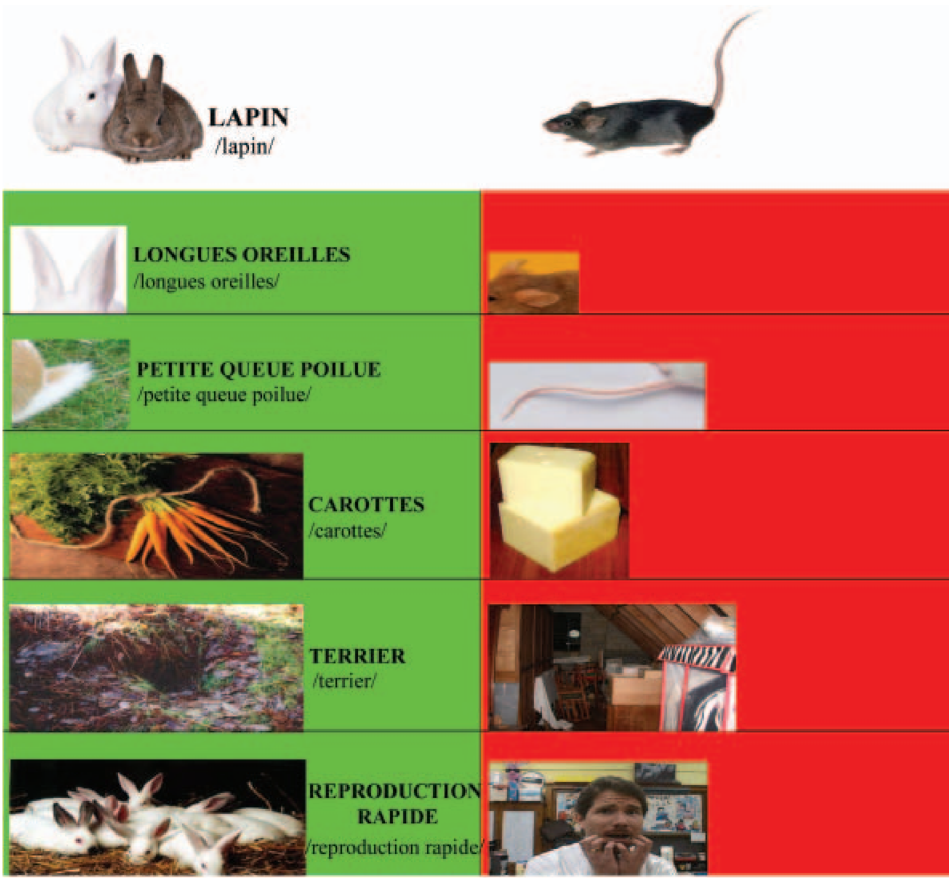
APPENDIX C

Design of the therapy task for the category, gesture, olfactory, and auditory attributes.

- **Category attributes**. Given that the coordinate items of the lists A and B belonged to the same semantic category, the sorting task presented in Phase 2 was adapted. Thus, the patient was presented each pair of target/contrast items simultaneously with sixteen photographs and their related (spoken and written) names. Each photograph and its related name depicted a semantic category (e.g., a photograph picturing various kinds of mammals and the word *mammals* depicted the category "mammals"). The patient was asked to point to the name and photograph corresponding to the target/contrast item pair (e.g., to the photograph of mammals and to the word *mammals* for the rabbit/mouse pair). For the optimal cue step, the therapist immediately showed the correct category to the patient. For the next cue steps, the patient was asked to perform the task on her own.
- **Functional attributes**. The functional attributes referred either to functional information (e.g., "eats carrots" for the item *rabbit*) or utilization gestures. Functional information was presented as photographs and the standard sorting task described in Phase 2 was applied. However, the utilization gestures associated with tools, musical instruments, and kitchen utensils were displayed by real gestures. Thus, for each pair of target/contrast items (represented here by real objects), the therapist performed six gestures of use in a random order (half correct, half incorrect) and the patient was asked to point the green column if they were correct for the target object. The regressive cue strategy was applied as described in the main text.
- **Olfactory attributes.** For the pair of target/contrast flower items, the therapist presented six perfumes (half related to the target item, half to the contrast item) in a random order. The patient was asked to place the bottles containing the perfumes corresponding to the target item in the green column and those corresponding to the contrast item in the red column. The regressive cue strategy was applied as usually.
- **Auditory attributes**. For the pairs of target/contrast items that were musical instruments and birds, the therapist presented six tape recordings of related typical noises. The patient was asked to point to those that were related to the target items. The regressive cue strategy was applied as usually.

APPENDIX D

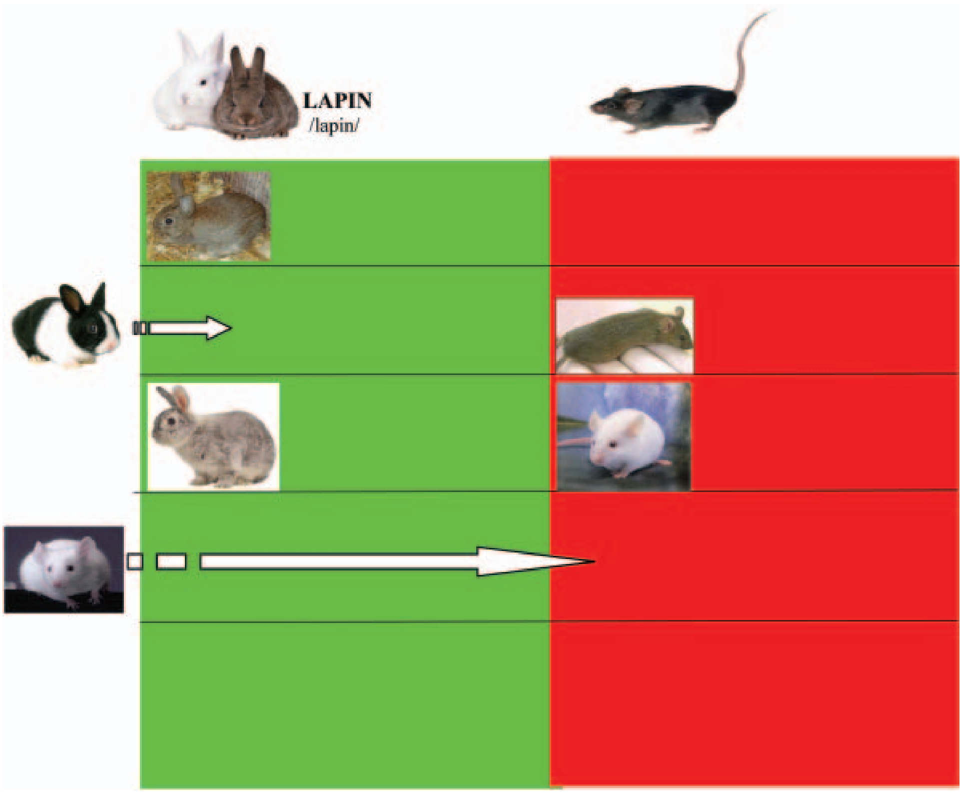
Illustration of the therapy task, Phase 1. The therapist places above the green sheet a photograph of the target item and, on the same sheet, photographs displaying the attributes of that item. On the red sheet, the therapist places a photograph of the contrast item and of its related attributes. The written and the spoken name of both the item and its properties were provided for the target items.



Translation of the verbal depiction of the semantic attributes related to the target item 'rabbit', from top to bottom: *has* long ears ; *has a* small hairy tail ; *eats* carrots ; *lives in a* burrow ; reproduces very quickly. The attributes related to the contrast item 'mouse' were never depicted verbally during therapy and were respectively: 'has short ears'; 'has a long fine tail'; 'eats cheese'; 'lives in attic'; 'frightens people'.

APPENDIX E

Illustration of the therapy task, Phase 2 (Part 1). Three new exemplars of the target and the contrast item were provided to DL in a random order and DL was asked to place them in the appropriate column (i.e., the rabbit exemplars in the green column, the mice exemplars in the red one).



APPENDIX F

Illustration of the therapy task, Phase 2 (Part 2). Three different photographs depicting a semantic attribute of the target item (e.g., "*mange généralement des carottes*"/"mostly eats carrots") and three photographs depicting a semantic attribute of the contrast item (e.g., "*mange généralement du fromage*/"usually eats cheese") were provided to DL in a random order. DL was asked to place the photographs in the appropriate column (i.e., "mostly eats carrots" in the green column, and "mostly eats cheese" in the red column).