COGNITIVE NEUROPSYCHOLOGY, 2003, 20 (2), 163–188

AN INFLUENCE OF SYNTACTIC AND SEMANTIC VARIABLES ON WORD FORM RETRIEVAL

Anne-Catherine Bachoud-Lévi
Service de neurologie, Hôpital Henri Mondor, Créteil, and INSERM UG21, Faculté de Médecine Paris XII, Créteil, France

Emmanuel Dupoux
Laboratoire des Sciences cognitives et psycholinguistique, Ecole Normale Supérieure, Centre National de la Recherche Scientifique, Paris, France

We report the case of DPI, an aphasic patient who shows a phonological impairment in production that spares certain syntactic and semantic categories. On a picture naming task, he produces mostly phonological paraphasias, and the probability of producing a correct response depends on the frequency and length of the target word. This deficit occurs in the presence of spared ability to find the grammatical gender of the items that he cannot name, intact conceptual knowledge, and very good reading and word repetition. Therefore, we conclude that DPI's deficit is restricted to the phonological retrieval of a correctly selected lexical entry. However, production errors are not uniform across semantic and syntactic domains. Numerals and names of days and months are totally spared compared to matched controls. In addition, abstract nouns and verbs are significantly *less* affected than concrete nouns, even when variables affecting phonological retrieval (frequency, length, syllabic structure) are controlled for. This suggests that a functional organisation in terms of semantic and syntactic variables exists at the level of phonological retrieval. We discuss these findings in light of current models of speech production.

Speech production involves a series of processes that begins with the activation of concepts and results in overt articulation (Butterworth, 1980, 1989; Dell, 1986, 1988; Dell & O'Seaghdha, 1992; Dell & Reich, 1981; Fay & Cutler, 1977; Garrett, 1975, 1992; Levelt, 1989; Shattuck-Hufnagel, 1979, 1992). When one wants to name the picture of an object, the structural description of the picture is used to activate a *conceptual representation* (typically, a bundle of semantic features). Although current models diverge on the terminology and mechanisms they refer to, most of them agree that two steps are necessary to access the phonological information for a given concept. We call them *lexical selection* and *word form retrieval*. We define *lexical selection* as the process that compares the activated conceptual representation to those stored in the lexical entries and selects the best match. For instance, the conceptual representation activated by the picture of a tiger will match several entries to

Requests for reprints should be addressed to Dr A-C. Bachoud-Lévi, Unité de neuropsychologie, Service de Neurologie, Hôpital Henri Mondor, 94010 Créteil, France (Tel: (33)1 49 81 43 01; Fax: (33) 1 49 81 23 26; Email: bachoud@lscp.ehess.fr).

We wish to thank S. Perperkamp and M. Petinato for very useful comments on the manuscript and F. Ricolfi for his help in the precise interpretation of the MRI. Discussion with Prs. G. Micelli and J. D. Degos† and the members of the INSERM U324 (Paris) and of the Laboratoire de Sciences Cognitives et Psycholinguistique (Paris) have been particularly helpful during the completion of our study. This study has been supported by the Assistance Publique/Hopitaux de Paris (Poste de Recherche Associé), as well as from a grant from the "Cognitique" program of the French Ministry of research and higher education.

†(deceased)

http://www.tandf.co.uk/journals/pp/02643294.html
DOI:10.1080/02643290242000907

various degrees, depending on their semantic overlap with the concept "tiger" (tiger, lion, eagle, etc.). We define *word form retrieval* as the process that recovers the phonological information associated with a selected entry, namely the *word form,* which consists in a sequence of phonemes together with metrical and suprasegmental information. In our example, the word form /táɪgər/, associated to the entry for "tiger" is retrieved. The word form is used to construct a detailed *phonological plan* to be executed by the articulatory system. In the General Discussion, we examine in more details how this two-step distinction is actually implemented in three current models of speech production (Caramazza, 1997; Foygel & Dell, 2000; Levelt, Roelofs, & Meyer, 1999).

In addition to this general organisation into sequential *processing levels*, an organisation in terms of *semantic domains* has been reported. Many studies report patients with selective sparing or impairment of objects versus actions, concrete versus abstract concepts, animate versus inanimate objects, or even finer-grained ones, such as fruits and vegetables versus other objects, or numerals versus non-numerals (see Caramazza & Shelton, 1998, for a review; Farah, Hammond, Mehta, & Ratcliff, 1989, and Humphreys & Forde, 2000, for a discussion). Categories like animals, humans, vegetables, or numerals correspond to distinct problems to solve for an organism embedded in an ecological situation (social interactions, reproduction, food gathering, hunting, etc.). One could argue that evolution has shaped the brain to process these different categories in dedicated circuits. A problem of considerable interest, then, is the relationship between these two principles of organisation: the sequentially organised processing levels, and the "ecologically" defined semantic domains. Specifically, is the organisation in domains restricted to the conceptual level, or has it also an impact across other processing levels?

It is perhaps not surprising that most of the studies supporting the existence of segregated semantic domains refer to conceptual level impairments. This is true for selective deficit or sparing of animals, vegetables or artefacts in patients who have semantic memory impairments (Hillis & Caramazza, 1991; see Caramazza & Shelton, 1998, for a review). Typically, patients fail to retrieve encyclopaedic knowledge related to an object (the use of an artefact, the typical habitat of an animal, etc.), whether the object is presented visually, in auditory, or in written form.

Less common are studies reporting that semantic variables are also relevant in impairments of lexical selection. Patients with such impairments have an intact conceptual representation but fail to select the appropriate lexical entry. This yields semantic paraphasias or anomic behaviour. With such patients, several dissociations have been reported between different semantic categories, such as fruits and vegetables (Hart, Berndt, & Caramazza, 1985) but also in less clear-cut categories, such as abstract versus concrete nouns (Franklin, Howard, & Patterson, 1995; Hillis, Rapp, & Caramazza, 1999). Syntactic domains such as open versus closed class items can also be selectively affected/spared in fluent aphasia (Coslett, Gonzalez-Royhi, & Heilman, 1984; Friederici & Shoenle, 1980). More fine-grained grammatical dissociations, such as nouns versus verbs, have also been reported (Baxter & Warrington, 1985; Breedin & Martin, 1996; Caramazza & Hillis, 1991; Daniele, Guistolisi, Silveri, Colosimo, & Gainotti, 1994; McCarthy & Warrington, 1985; Miceli, Silveri, Nocentini, & Caramazza, 1988; Rapp & Caramazza, 1998; Silveri & Di Betta, 1997). These results suggest that lexical selection preserves some of the organisation principles that operate at the conceptual level.

The question we raise here is whether such organisation also holds at the next step down the line, namely, word form retrieval. Prima facie, this would be surprising. In principle, word form retrieval should only care about information relative to the phonological shape of the words (word length, stress pattern, surface word frequency, syllabic structure; see Jescheniak & Levelt, 1994; Levelt, 1989), and it is unclear why semantic or grammatical categories should be relevant at this level. Yet, Cohen, Verstichel, and Dehaene (1997) suggested that numerals are processed differently from other categories, even down to phonological processing levels. They reported a patient who was producing primarily phonological paraphasias, typically nonwords that were phonological neighbours of the target word. Therefore, they concluded that the patient was able to correctly select the word lexical entries, but was having problems in word form retrieval or even in phonological planning. Yet, although their patient was heavily impaired when naming or reading concrete nouns, he made virtually no phonological errors with numerals (instead, he made lexical selection errors). The authors suggested that the topographical segregation of numerals in the conceptual system propagates along the speech production pathway, down to word form retrieval.

Such a conclusion is very provocative, since it suggests that the brain does not necessarily organise each linguistic level along dimensions that are mostly relevant from either a functional or linguistic perspective, but rather, that ecologically/conceptually defined categories are segregated into distinct pathways, even down to quite peripheral levels. Note, however, that as Cohen et al. (1997) recognise, numerals are special in many ways. They are special not just in terms of their conceptual and ecological characteristics, but also regarding their syntactic and morphological structure. Numerals indeed constitute a very specific syntactic category within the determiner system and have quite unique combinatorial properties. They are based on a finite set of number words, and can combine recursively with a specific syntax to represent each of the infinitely many natural numbers. In this sense, they constitute a unique subpart of language, and one could conceive that the brain dedicates specialised networks to deal with them, even in terms of their phonological realisation. It remains to be seen, then, whether such segregation can be observed in domains other than numerals.

In this paper, we present a patient who adds further evidence in favour of semantic and syntactic organisation of word-form retrieval. The nature of his production errors clearly indicates a word form retrieval impairment. Yet, as in Cohen et al.'s case, numerals were spared (without any selection errors); in addition, the deficit affected nouns more than verbs, and within nouns, it affected concrete nouns more than abstract ones.

CASE REPORT

Medical history

DPI was a 68-year-old, right-handed, retired medical doctor. One year before examination, he had a stroke leading to a Wernicke aphasia and a right hemiparesis. The motor deficit disappeared within a few hours but aphasia remained severe. A CT scan (at admission) and an MRI (1 year later) confirmed a left temporal artery stroke (Figure 1). He was transferred after his stroke to a rehabilitation centre, and because of his insufficient progress he was addressed to our centre.

General language assessment

At the onset of testing, DPI was still jargon aphasic. For example, when asked to define the usage of an ashtray, he said: "Une scie possible pour /ãtrənir/ un besoin de certains blancs de /rəblɛze/ quelque chose pour /nesesœr/ ce qui devant à quelqu'un." (a possible saw to /ãtrənir/ a need for certain whites to /rəblɛze/ something to /nesesœr/ that in front of to someone). General investigation of language was conducted using a French version of the Boston Diagnostic Aphasia Examination (Mazaux & Orgogozo, 1982) (see Table 1): Fluency, syntax, prosody, and articulation were normal. Picture naming yielded mostly phonemic paraphasias. Comprehension and repetition were broadly satisfactory: Simple sentences were correctly understood while very complex or long sentences were not. Word repetition was good (8/10) and better than sentence repetition. Reading and written comprehension were preserved but writing was impaired. Forward and backward digit spans were both at 5.

During 2 months of assessment, DPI's performance improved significantly and remained stable thereafter. Experimental investigation was started after performance stabilisation and focused on the oral speech disorder. Additional tests were conducted to draw a global picture of DPI's linguistic abilities concerning words. In the following sections, we try to locate DPI's deficits within a standard neuropsychological model of language

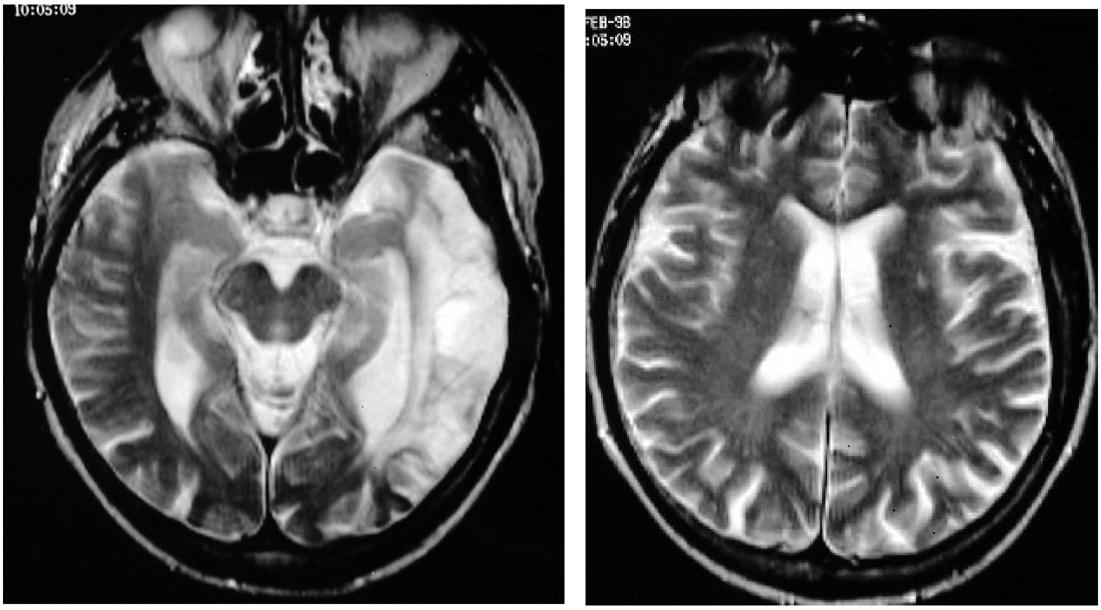


Figure 1. *MRI image of the lesion in DPI. The lesion encompassed the left temporal artery territory including the superior, medial, and inferior temporal gyri (T1, T2, and T3) but spared T4, T5, and the anterior temporal lobe.*

processing that incorporates speech perception and word recognition, object identification, and word production. In this model (see Figure 2) *phonological output lexicon* refers to a process that encompasses both lexical selection and word form retrieval in the oral modality. The *input-to-output phonological route* links the phonological representation extracted from spoken inputs to the phonological representation that can initiate articulation. This is the route that allows one to repeat nonwords.

Naming

Picture naming was assessed with a list of 70 pictures, varying name frequency and number of syllables. DPI made several errors (33/70 correct), especially with long and infrequent items. The errors were mostly phonological approaches and phonological paraphasias (for example, the picture of an helicopter "*hélicoptère*" was named /eliʒotɛrmɛtr/). Yet, even for words that yielded an error, DPI could give numerous types of information about the target name, as in the tip-of-the-tongue phenomenon (Brown & McNeill, 1966); he could often provide the gender and the number of syllables, and always provided accurate semantic information (for example: for an arrosoir (*watering can*), he said "Je le sais, j'en prends tous les jours pour mes fleurs.... C'est 3 syllabes ... /arâdyr/ ... non ... arrosoir". (*I know it, I take it everyday for my flowers...it's 3 syllables ...* /arâdyr/, *no ... watering can*).

Conceptual knowledge

We presented DPI with a word–picture matching task in both the oral and the visual modality (Table 2). The pictures (N = 16) were presented together with a noun, which was either the name of the picture, a semantically related word, or a phonologically related word. In the oral modality, for instance, the picture of a pipe was presented three times, once with the word "pipe", once with "cigarette", and once with "pile". The order of the three conditions was randomised across pictures, and the patient was asked to provide a yes/no response. In the written modality, the three alternatives were presented simultaneously, and the patient had to point to the correct response. DPI was perfect in both tasks (48/48 correct responses in the auditory

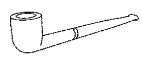
Table 1. *Performance of patient DP on a French version of the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1972; Mazaux & Orgogozo, 1982)*

Subtests	*Scores*
Auditory comprehension	
Word discrimination	65/72
Body-part identification	17/20
Command	13/15
Fluency	
Articulation rating	7/7
Phrase length	7/7
Verbal agility	8/14
Automatic speech	
Automatised sequences	9/9
Reciting	0/2
Repetition	
Repetition of words	8/10
Concrete sentences	5/8
Abstract sentences	2/8
Reading aloud	
Words	30/30
Sentences	10/10
Naming	
Responsive naming	20/30
Confrontation naming	85/105
Animal naming	14/23
Body-part naming	17/30
Paraphasia	
Neologistic	8/16
"P. verb. Synt"	6/24
Written comprehension	
Literal discrimination	10/10
Verbal	8/8
Spelled words	5/8
Word-pictures	10/10
Text reading	6/10
Writing	
Mechanics	3/3
Automatic writing	47/47
Dictation	15/15
Written denomination	10/10
Graphical evocation	6/10
Sentence dictation	9/12
Description	3/4

presentation and 16/16 in the written presentation).

These results suggest that both word comprehension and picture identification are preserved. In order to assess processing at the conceptual level in a more direct way, we conducted further tests on 27 pictures that DPI was unable to name on at least three separate sessions (14 artefacts, 4 vegetables, 7 animals, and 2 body parts). Five nonverbal tests were constructed along the lines of Shelton and Caramazza (1998); they did not require oral answers. They were followed by a verbal questionnaire that tested conceptual knowledge about the same set of pictures.

Table 2. *Word-picture matching task*

Picture (N = 16)	*Test word*	*% Responses*
	Identity "pipe"	100
	Semantic foil "cigarette"	0
	Phonological foil "pile"	0

In the *anomalous picture detection task*, we constructed an anomalous picture for each picture in the set by changing a detail (a leg for animals, leaves for flowers, etc). DPI was asked to classify the pictures as anomalous or normal and to point to the anomalous detail. He scored 27/27 correct. In the *picture completion task*, a fragment of each picture was deleted. DPI was asked to complete the incomplete picture with one of four fragments extracted from different pictures. The pictures and fragments were made not to match perceptually (different extraction, rotation, zoom, etc.). Again, DPI was flawless (27/27 correct). Category membership was tested in an *intruder detection task*. DPI was flawless (27/27) when asked to detect the intruder among four pictures (three belonged to the same category and one did not). Functional knowledge was tested with the pictures of artefacts in a *functional matching task*. The target picture, a functionally related picture, and two distracters were presented, and DPI was asked to point to the related picture. Again, he performed perfectly (14/14). In an *object-colour matching task*, DPI had no problem in pointing the correct colour of the vegetables (4/4) among three incorrectly coloured distracters.

Finally, we assessed his conceptual knowledge using a questionnaire. Eight types of questions were asked about the pictures, for example: "Is it edible?," "Does it live in France?," "Does it have seeds?" (for vegetables), "Does it fit in a shoe box?" etc. To avoid interference with the verbal output deficit, only yes/no responses were requested. Performance was very good (122/149). Errors were restricted to two questions that were more pragmatic than conceptual ("Is it usually in a house?" and "Can we buy it?").

To sum up, using non verbal picture tasks, word–picture matching, or verbal questionnaire, the conceptual knowledge of the patient seems intact.

Auditory perception

Perfect performance in the picture-word matching task explained above suggests intact auditory perception. However, this is insufficient because the presence of a picture adds top-down information that could lead to correct responses in spite of subtle auditory deficits (although his production of the pictures is itself heavily impaired). We ran a phonological matching task using a list containing 64 words and 32 nonwords, half monosyllabic, half bisyllabic, matched in syllabic structure (List A; see the Appendix). Across the two lengths, the words were matched in frequency, and the nonwords in number of neighbours. The items were presented in pairs, with either the same stimulus repeated, or with a change in one consonant. The patient had to decide whether the two members of the pair were identical or not. The performance was quite good, although not perfect (91% for the words and 92% for the nonwords).

Reading

Analogously to naming, reading aloud words and nonwords involves phonological planning and articulatory processes. Comparing reading with naming can thus help to understand the level of the production deficit. Reading aloud was tested using the items in List A; the patient was 88% correct with words and 91% with nonwords. We further tested reading with a new list containing 100 words of different lengths (20 words of 4, 5, 6, 7, and 8 letters, respectively). The performance was 90% correct when the first response was taken into account and 99% after spontaneous self-correction. This good, albeit not perfect, reading performance suggests that phonological planning is preserved in this patient, and that this level alone cannot account for the high rate of phonological paraphasia observed in the naming task.

Repetition

To check for a disorder in the input-to-output phonological route, spoken word repetition was assessed in three tasks: (1) immediate repetition, in which the examiner produced the target item and the patient had to repeat it immediately; (2) delayed repetition with a delay of 4 seconds between the target and the repetition; (3) delayed repetition with articulatory suppression: DPI was asked to recite the alphabet from letter "A" to letter "V", which took approximately 15 s, before giving the response. Delayed repetition tasks were used to check for the articulatory loop and the articulatory buffer. In all these tasks, the same material was used (List A).

Globally, DPI was impaired in repetition, more so for nonwords (52% correct) than for words (77% correct), $\chi^2(1) = 4.42$, $p = .035$. There was no difference in performance for the three repetition tasks ($p < .05$) (see Table 3 for a summary of the results). Self-corrections improved performance. Performance in repetition was better than in naming but not flawless. The impairment in nonword repetition indicates a deficit in the input-to-output phonological route. Better performance for word compared to nonword repetition can be interpreted by the existence of an alternative route through the lexical/conceptual system[1]. Finally, better overall results in repetition than in naming

[1] The lexical route is also impaired, as the naming data shows. Indeed, using the large naming dataset that we introduce in the next section, we can estimate that the error rate of the lexical route is around 49%. The performance in nonword repetition allows us to estimate the error rate of the nonlexical route at 48%. We can hence compute the theoretical error rate in word repetition: It is equal to the probability of failing in both routes, hence the product of the error rate of the lexical and nonlexical routes, respectively. This yields a theoretical error rate of 23% for the repetition of words, which is very close to the observed rate.

Table 3. *Percentage correct in reading, phonological matching, and repetition for words and nonwords on List A*

	Reading	*Phonological matching*	*Immediate repetition*	*Delayed repetition (4s)*	*Delayed repetition (15 s) plus articulatory suppression*
Words (*N* = 64)					
First response	88%	91%	80%	75%	77%
Final response			81%	77%	86%
Nonwords (*N* = 32)					
First response	91%	92%	55%	58%	42%
Final response			55%	58%	48%

suggest, as in the case of reading, that a phonological planning disorder is unlikely to explain the naming deficit.

Summary

DPI was quite good in all tasks except in picture naming and in repetition, especially for nonwords. Given the perfect performance at the word–picture matching task and DPI's abilities to provide semantic information on misnamed items, semantic and conceptual knowledge seemed totally spared. Similarly, the good performance in nonword reading and relatively preserved word repetition suggest spared phonological planning. Considering the very good performance in the phonological matching task, the impaired performance in nonword repetition most likely resulted from a deficit in the input-to-output phonological route rather than from an auditory perception deficit; indeed, the comprehension task used phonological distracters that could not be discriminated unless in the presence of spared perception abilities. To conclude, DPI's pattern of performance may result from two independent impairments, one in the input-to-output phonological route, another one in the output phonological lexicon. This is schematically represented in Figure 2.

The next section provides a detailed analysis of the error pattern in an attempt to locate the naming deficit precisely within the output lexicon.

ASSESSING THE LOCUS OF THE PRODUCTION DEFICIT

The general language assessment allows us to discard a deficit in either conceptual processing or phonological planning. In this section, we analyse more systematically the patient's pattern of performance in naming; by trying to discriminate between an impairment of lexical selection versus an impairment of word form retrieval.

A total of 238 pictures of concrete nouns were presented across several sessions for confrontation naming. Some of them were presented several times across different sessions, resulting in 601 picture naming trials. For each trial, the examiner transcribed all DPI's attempts to provide the response. Incomplete responses were excluded. For example, given the target "entonnoir" (*funnel*), DPI produced /ã…/ and then /ãtiʒaf/. We only transcribed the complete response, namely, /ãtiʒaf/. The gender (masculine or feminine) was also coded when the patient spontaneously produced an article before the items. On several occasions when DPI failed to produce the correct answer, he was asked for the gender and/or the number of syllables of the target word.

DPI found the correct response on the first attempt in 303 trials (50.4%) and in 145 more trials after spontaneous self-correction, giving him a final performance of 74.5% correct. He found the correct response after a number of attempts ranging from 1 to 17 (mean 3.4). Among the 153 remaining trials

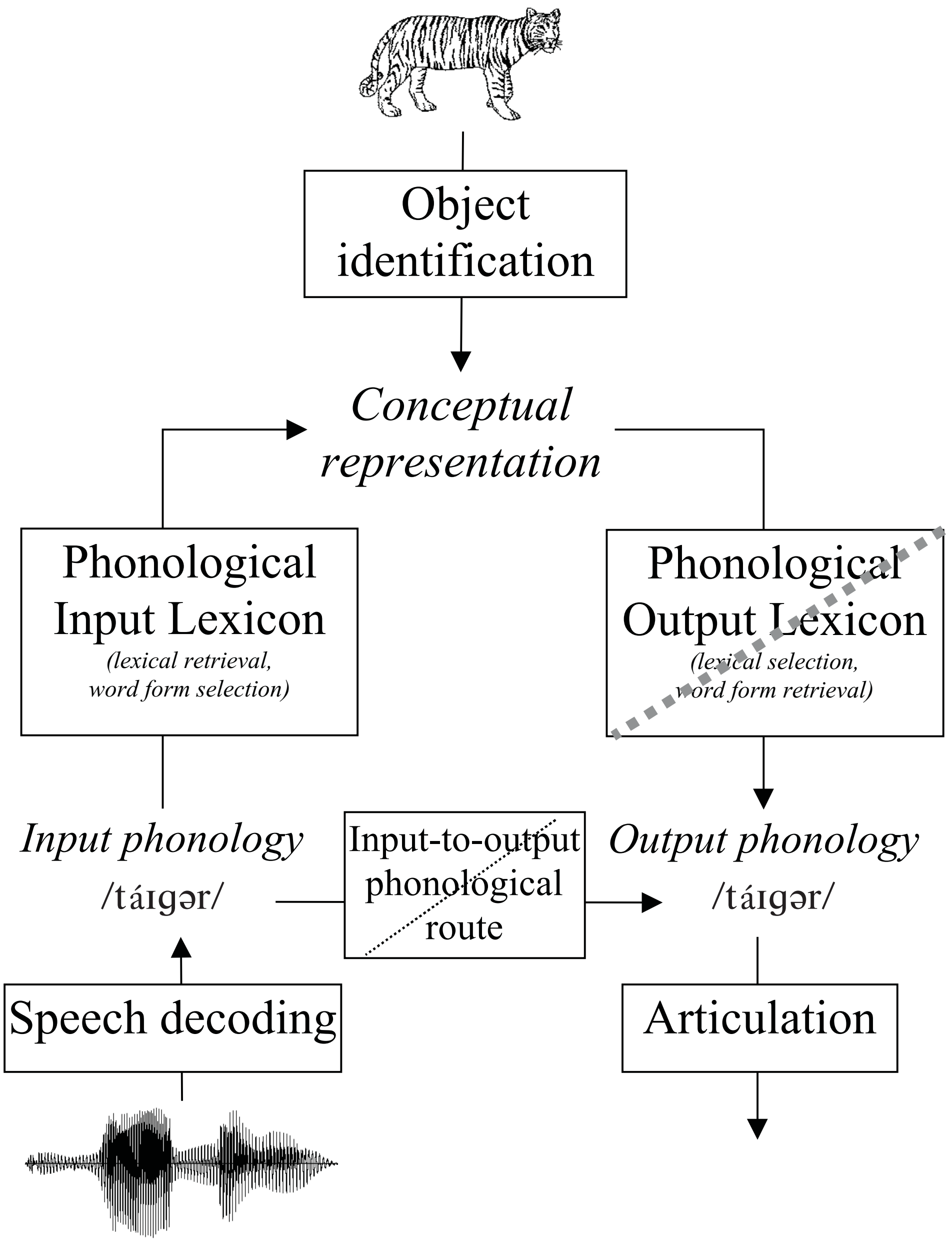


Figure 2. *Schematic description of the deficit of patient DPI. Processes that are diagnosed as impaired in the patient are crossed with dotted lines.*

where he gave up, he was given a phonological cue (first phoneme or first two phonemes) in 65 cases. This allowed him to find the correct response in 38 more cases.

Correct lexical selection: Gender and number of syllables

Because gender or number of syllables of a word cannot be provided unless the correct lexical entry has been selected, it can be used to indicate whether lexical selection is affected in DPI's performance. Knowledge about the number of syllables was checked in 99 misnamed pictures. He was asked to provide the number of syllables either with a number or by knocking on the table. DPI was accurate in 71 occasions (70%), and doubtful on 7 occasions (he hesitated between the correct answer and the correct answer plus or minus one syllable). He correctly provided the gender in 95% of the trials. This excellent performance suggests that DPI is mostly unimpaired in lexical selection, and that his naming problems are rather due to difficulties in retrieving or assembling the phonological forms of these words.

Variables affecting number of correct responses: Length and frequency

The previous analysis suggests intact lexical selection but does not positively indicate that word form retrieval is impaired. To demonstrate it more directly, we checked whether phonological variables influence DPI's performance. Psycholinguistic experiments show that word length affects the recovery of the word form, or its transmission to phonological planning (Eriksen, Pollock, & Montague, 1970; Klapp, Anderson, & Berrian, 1973; but see Bachoud-Lévi, Dupoux, Cohen, & Mehler, 1998). Similarly, word frequency has been argued to tap word form retrieval (Jescheniak & Levelt, 1994). We analyse the role of these two variables using the first complete response provided by the patient for each item.

DPI tended to make fewer errors with short words (80% correct for words of two phonemes) than with long words (16% correct for words of eight phonemes). Regression analyses revealed that number of phonemes accounted for 16.1% of the variance ($p < .001$) and Log word frequency for 13.1% of the variance ($p < .001$). These two variables together accounted for 21.4% of the variance ($p < .001$).

Of course, frequency and length are usually (negatively) correlated. To verify the independent effect of these two variables, we ran the two following analyses (see Figure 3):

1. We sorted the data set to construct a group of high- and a group of low-frequency items while neutralising the number of phonemes. Pictures were grouped in five classes of number of phonemes (2–3, 4, 5, 6, and 7–9 phonemes), removing items with more than 9 phonemes. Each class was then split into two equal groups with matched length, one containing the more frequent items (HF, average frequency: 27.6 per million), the other one the less frequent ones (LF, average frequency: 5.1 per million). An ANOVA by item revealed a frequency effect, $F(1, 218) = 11.18$, $p < .001$, that did not interact with length ($F < 1$).
2. Similarly, to evaluate the effect of length, we neutralised the effect of frequency. We sorted the data set into five frequency bands containing 46 pictures each (we have removed rare items with a frequency of less than 0.5 per million). Each band was then split into two groups of words, short or long, as a function of the number of phonemes, and matched in frequency. The short items had on average a length of 3.6 whereas the long items were 5.7 phonemes long. An ANOVA by items found an effect of number of phonemes, $F(1, 220) = 14.19$, $p < .0001$, which did not interact with frequency.

In brief, frequency and length contributed significantly and independently to the probability of making a correct response on the first attempt.

Phonological nature of the jargon

The paraphasias of the patient were analysed using the total of DPI's 1454 incorrect productions (first as well as subsequent responses). The patient exhibited a very characteristic approach strategy, trying to produce the target by changing a few

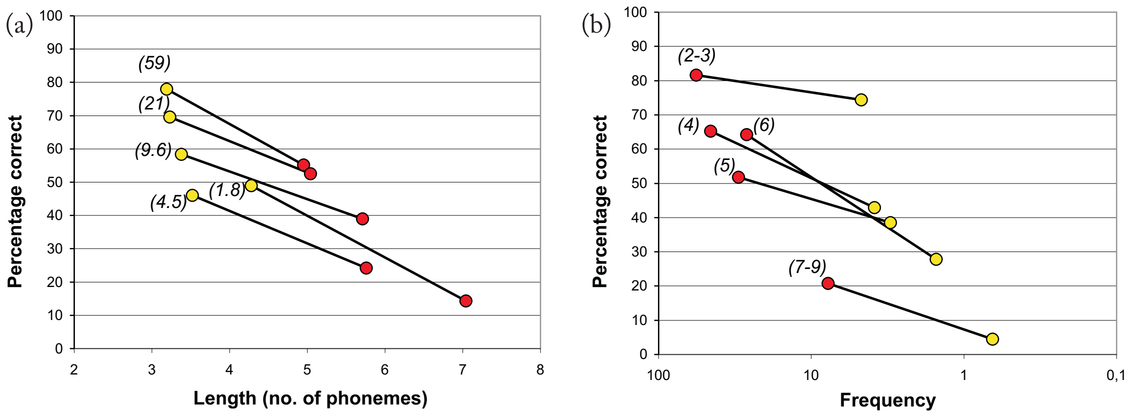


Figure 3. *(a) Shows the effect of number of phonemes on percentage correct naming responses, with word frequency (shown in parentheses) controlled for. (b) Shows the effect of word frequency on percentage correct naming responses, with number of phonemes (shown in parentheses) controlled for.*

phonemes at a time (1.8 phonemes on average between two successive attempts). For example, for the target "kangourou" (/kãguru/, *kangaroo*), he would produce, successively: /kaʒaku/, /kõriku/, /garigu/, /katigu/, /gatigu/, and /kõdiʒu/. This suggests that the nature of the problem was to retrieve or assemble the phonological form of the word.

To understand the error pattern better, paraphasias were classified into six categories: visual errors, phonemic paraphasias, semantic paraphasias, mixed errors, and other verbal errors. Sometimes, we had to take into account all responses in order to determine the word that the patient had in mind—and checked it with him at the end of the trial. Errors were visual when the patient provided an acceptable alternative interpretation of an eventually ambiguous picture (less than 5% of the trials). Visual errors were reclassified as correct responses with the intended target instead of the planned target. A phonemic paraphasia implied that the target and the response shared more than half of their phonemes. An error was considered to be a semantic paraphasia when two independent raters considered that there was a semantic relationship between the target and the response (a more fine-grained analysis of these errors is discussed below). A phonemic paraphasia could occur on top of a semantic one and was conservatively coded as semantic; for example /ʒadwar/ instead of "jaguar" (*jaguar*) when the target was "tigre" (*tiger*). Mixed errors were errors that simultaneously met the criteria for phonemic and for semantic paraphasia: (an example is /rabo/ ("rabot," *plane*) instead of /rato/ ("rateau," *rake*). Finally, verbal errors were word or nonword responses that were not related semantically or phonologically in any obvious way to the target.

The distribution of errors is given in Table 4. Phonemic paraphasias dominated the error corpus, followed by verbal errors. Half of the semantic paraphasias were phonological on top of semantic. A closer look at the semantic errors revealed that 10.5% should be classified properly as semantic paraphasias (associates, or same-category members). The remainder consisted of superordinate responses (e.g., pine–tree), naming of a detail of the picture (volcano–crater), and paraphrases (scarecrow–funny man). These responses can be considered as response strategies in the face of a difficulty in finding the correct word form, rather than semantic errors per se.

Table 4. *Distribution of errors in naming*

Error type	*N*	*%*
Phonological	671	46.1
Semantic	196	13.5
Mixed	14	1.0
Verbal	587	404
Total	1454	100

In the following, we attempt to demonstrate that DPI's verbal errors and phonemic paraphasias emerged from a common deficit in word form retrieval. Responses were predominantly nonwords (75% of the phonological errors and 79% of the verbal errors) that were all phonotactically legal in French. A priori, word responses can be interpreted as lexical selection errors, however they can also be considered as phonological errors that result in a word just by chance. Indeed, there is a nonzero probability of obtaining a real French word, just by randomly assembling phonemes together, especially if the word is short. Taking into account the distribution of lengths in DPI's productions, as well as the phonotactic probabilities of sequences of phonemes in French, we estimated that the probability of obtaining a word by chance was 21.4%, a percentage not significantly different from what was actually observed, $\chi^2(1) = 0.92$, $p > .1$.[2] Moreover, the ratio of word over nonword responses strongly declined with response length, which is exactly the expected pattern if word responses are just due to chance. Regarding verbal errors, we found that they generally tended to preserve the number of syllables of the target (78% exact match, 18% off by one syllable, and 5% off by more) better than would be obtained by random production (respectively, 33%, 42%, 24%), $\chi^2(2) = 37.4$, $p < .0001$.[3] This indicates that verbal errors result from an incompletely retrieved word form.

To sum up, DPI produced mostly phonemic paraphasias and verbal errors. These errors were mostly nonwords, and the number of words produced did not differ from what would be expected with random phonological errors. The errors globally preserved the number of syllables with the target words and shared on average half of the phonemes of the target word. This suggests that the errors were due to a problem in either the lexical representation of the word form, or in the access to this representation.

Deficit of the word form versus the retrieval process: Consistency of the errors

Consistency in item performance across different trials has been used to indicate the nature of the deficit (Warrington & Shallice, 1984). High consistency across trials may indicate that specific lexical representations are degraded, whereas low consistency may indicate a deficit in retrieving or in the transmission of otherwise intact information. In an attempt to discriminate between these two options, we assessed consistency, using items of moderate difficulty (that is, we avoided items that were too short or too long). We thus selected the 127 items that were four, five, and six phonemes long and had been tested at least twice. These items yielded an average correct performance of 45% (on the first attempt), and showed a degree of consistency of 62%. This consistency score was significantly higher than the chance score of 33%, $\chi^2(1) = 20.4$, $p < .0001$, obtained by computing the theoretical consistency of each word taking word length and number of repetitions into account.[4] Inspection of the consistent items failed to reveal any underlying regularity. The performance of the patient was thus significantly more consistent than chance level, but not completely consistent.There were both items that were systematically impaired or preserved, and items that were inconsistent from trial to trial. Such variability suggest an impairment of both specific words forms and fluctuations in the retrieval process.

[2] In order to obtain such a baseline probability, we ran a Monte Carlo simulation by generating 140,000 nonwords that had a random arrangement of phoneme respecting both the phonotactic probabilities of French and the distribution of syllabic structures produced by the patient. We then counted how many words were created by this random process. The algorithm selects legal half-syllables (onset + nucleus, or nucleus + rime), taking into account their frequency of occurrence in the language, and concatenates them in order to obtain a given syllabic shape.

[3] The chance level was computed by randomly reassigning the productions of the patient to a target word, and counting how many of the cases produce a match in number of syllables.

[4] The probability of consistent responses is according to the binomial law: $p^n + (1 - p)^n$, where p is the probability of errors for this type of word and n is the number of repetitions.

Discussion

The general pattern of performance of DPI allows us to locate his main production deficit in word form retrieval. A lexical selection impairment was dismissed because the patient was correct in determining the gender of the item in 95% of the misnamed pictures. Since gender information in the case of inanimate pictures (or animals) is not related to conceptual information, it can only be recovered from the lexicon. Similarly, the correct number of syllables was provided in more than 70% misnamed pictures, suggesting that lexical selection was correctly attained in a large number of cases.

Moreover, several arguments positively pointed toward a deficit in word form retrieval. First, phonological variables such as word frequency and length affected performance. Second, and more important, the errors were mostly of a phonological nature. Phonemic paraphasias or verbal errors (86% of the errors) were produced as approximations to the target item. They shared the number of syllables with the target in 78% of the cases. Finally, the errors were mostly nonwords, and the rate of real word production was not significantly higher than what would be expected on the basis of chance.

In brief, the pattern of results suggests a specific impairment in word form retrieval of correctly selected lexical entries. Let us now turn to the more puzzling aspect of the errors in DPI: their sensitivity to syntactic and semantic variables.

EFFECT OF SYNTACTIC AND SEMANTIC CATEGORIES

Informal testing revealed that DPI was relatively unimpaired with verbs and never made errors with numerals. Dissociation between performance with nouns and with verbs have been largely reported in the literature (Baxter & Warrington, 1985; Berndt, Mitchum, Haendiges, & Sanson, 1997; Caramazza & Hillis, 1991; De Renzi & Di Pellegrino, 1995; Goodglass, Klein, Carey, & Jones, 1966; Hillis & Caramazza, 1995; McCarthy & Warrington, 1985; Miceli et al., 1988; Miceli, Silveri, Villa, & Caramazza, 1984; Rapp & Caramazza, 1998; Zingeser & Berndt, 1990). These studies cover a broad range of deficits, but never concern patients with a phonological disorder. As for the category of numerals, very few studies have documented in detail a selective sparing of numerals in the context of a phonological disorder (Cohen et al., 1997).

In the next sections, we compare the production of nouns versus verbs, as well as numerals versus other categories in a series of experiment that control for phonological variables (frequency and length).

Syntactic categories: Nouns versus verbs

In order to substantiate our informal observations with more controlled materials, we ran four experiments comparing nouns and verbs using definition naming, picture naming, and sentence completion. The results are displayed in Table 5.

Definitions

The patient was presented with 60 definitions: 30 for verbs, and 30 for nouns. There were 10 monosyllabic, 10 bisyllabic, and 10 trisyllabic words in each category (half high frequency and half low frequency). Definitions were presented simultaneously in the visual and oral modality. Here, the responses were scored at the end of the phonological approaches. Performance with verbs was significantly better than with nouns, $\chi^2(1) = 28.02$, $p < .0001$.

Picture naming

Forty-eight pictures (24 action verbs and 24 objects) were used (see Appendix). DPI was asked to name the picture orally. The list was run twice. Unfortunately, one of the verb pictures was omitted in both sessions.

DPI was instructed to give the verbs in the infinitive form. When he produced the correct item but in a wrong morphological form, he was asked to correct his answer. Hence, the response was considered as correct only when morphologically correct. Performance tended to be better with verbs (35/46) than with nouns (32/48), but it did not reach significance ($p > .5$). However, semantic paraphasias were more frequent in responses for verbs (15.2%)

Table 5. *Percentage of correct responses in production of nouns, verbs and adjectives*

Correct naming	*N*	*Nouns*	*Verbs*	*Adjectives*	*p between verbs and nouns*
Definitions	60	70.0%	100%		*
Oral picture naming	47 × 2	66.7%	76.1%		n.s.
Written picture naming	47	20.8%	50.0%		.07
Sentence completion (I)	90	26.7%	79.3%	27.7%	*
Sentence completion with homophones (II)	42	26.2%	54.7%		*

*$p < .05$.

than for nouns (4.2%), whereas phonological paraphasias were more frequent in responses for nouns (25%) than for verbs (8.7%), $\chi^2(1) = 4.55$, $p < .04$.[5]

Sentence completion

To elicit the production of items of different categories, we constructed sentences that provided a highly predictive context for a target word. The sentences were presented to the patient without the target word (it was replaced by a hum), and the patient had to provide the missing word. Ninety such sentences were constructed; 30 with a target noun, 30 with a target verb, and 30 with a target adjective. Targets were matched in frequency and length and also for their position within the sentence.

Alternative responses to the target word were considered correct if they were syntactically and semantically acceptable (this occurred in four adjectives, two verbs, and one noun). Four sentences did not elicit any answer and were removed from the analysis. Responses were correct for 8/30 nouns, for 10/27 adjectives, and for 23/29 verbs. Performance was similar with adjectives and with nouns, $\chi^2(1) < 1$. In contrast, performance was better with verbs than with nouns, $\chi^2(1) = 13.08$, $p < .001$, and adjectives, $\chi^2(1) = 7.60$, $p < .01$. Errors were mostly verbal in nouns; there were also few semantic and phonological paraphasias in all categories.

Sentence completion with noun–verb homophones

In the three experiments mentioned above, DPI named verbs better than nouns or at least produced less phonemic paraphasias in verbs than in nouns. One might argue that the verbs and the nouns differed in their morphological complexity or in another uncontrolled phonological parameter. To control for potential phonological differences, 21 pairs of homophonic nouns and verbs, e.g., "boucher" (*butcher* or to *block*) were selected (see List B in the Appendix). DPI was asked to name them in a sentence completion task. The experiment was run twice. Performance was again better with verbs (23/42) than with nouns (11/42), $\chi^2(1) = 5.99$, $p < .02$, while performance in 18 control subjects was similar with nouns (97.1% ± 3.7 correct) and with verbs (96.8% ± 3.6).

Semantic categories: Numerals, body parts, and more

Cohen et al. (1997) found no phonological paraphasia with numerals contrary to other lexical categories. The authors suggested that numerals may be processed in a special way for one of several reasons:

1. Numerals may constitute a specific syntactic category (quantifiers).
2. Numerals may constitute an ecological semantic category in that many animals possess mechanisms to represent quantities and rates (see Dehaene, 1997).

[5] Interestingly, in a written naming task with the same stimuli, DPI produced similar errors with a score of 17/24 for verbs and 6/24 for nouns, $\chi^2(1) = 8.35$, $p = .004$. This was obtained when counting as correct morphological variants (infinitive forms) and phonologically correct but misspelled responses (e.g., "coure" for "court," /kuR/, *run*). The large presence of homophonic misspellings suggests that DPI has a severe writing impairment compensated through the use of his relatively spared phonology. However, since the patient had a further accident and was unavailable for testing, we could not explore this hypothesis in detail.

3. Numerals are learned in recited sequences during childhood. Like months and days, they are particularly overlearned and can be uttered as automatic speech.

4. Numerals—like body parts and colours—constitute a small lexical category.

Here, we test these hypotheses in five naming experiments with words belonging to different semantic categories (numerals, ecological categories, finite categories, and automatic series). For each category, we selected control items among the 238 pictures of our naming data set. These control items were selected in categories others than the one tested, using an AWK script programmed to select the set of items that were the best match in terms of length and frequency (and when possible, syllabic structure) to the target items. This selection procedure was, of course, blind to DPI's performance on the selected items. The results are displayed in Table 6.

Numerals

Twenty-two numerals were selected. In order to limit the contribution of automatic recitation, number naming was explored in three tasks: Arabic digits reading, number bisection ("What is the number in the middle between 3 and 7?"), and simple additions. DPI was surprisingly accurate with numerals (100% correct responses in all tasks) which was significantly better than performance with the 22 control pictures matched for frequency, number of syllables, and number of phonemes (72.3% correct), $t(21) = 3.10$, $p < .005$.

"Ecological" categories: Animals, vegetables vs. artefacts

Sixty pictures belonging to three different "ecological" categories (see Caramazza & Shelton, 1988, for a review) were tested: 20 artefacts, 20 animals, 20 vegetables, matched for number of phonemes, frequency, and number of phonological neighbours. Performance was similar across categories (artefacts 40%, animals 40%, and vegetables 30% correct responses), $\chi^2(2) = 0.57$, $p > .1$. Likewise, the number of phonological or semantic paraphasias did not differ across categories.

Finite categories: Colours and body parts

Twenty-one body parts were either shown by pointing at the body of the experimenter or on a drawing. Performance did not differ with body parts (71%) and with the 21 control items (living and nonliving objects) matched in number of phonemes, number of syllables, and frequency (81% correct responses, $p > .1$). DPI made five phonological errors (in body parts) and failed to respond on one occasion.

Naming of 11 simple coloured discs was compared to naming of 11 pictures matched in number of syllables, number of phonemes, and frequency. The task was run twice in separate sessions. Performance was similar with colours and with matched

Table 6. *Percentage of correct responses in production of nouns as a function of semantic categories*

Correct naming	*N*	*Test pictures*	*Control pictures*	*p between test and control*
Numerals	22	100%	76%	*
"Ecological" categories				
Artifacts	20	40%		n.s.
Animals	20	40%		between
Vegetables	20	30%		categories
Finite categories				
Body parts	20	70%	81%	n.s.
Colours	11 × 2	73%	90%	n.s.
Automatic series (task: bisection)				
Months, days	19	100%	63%	*

pictures ($p > .1$). However, colour naming yielded colour approximations (27%) rather than phonemic paraphasias (0%) (for instance, the red disc yielded the response "rose" *pink*). As these errors might relate to perceptual problems with colours, this issue was not pursued further.

Automatic series: Months and days

When asked to recite months and days, DPI was totally accurate. To compare this with the number naming experiment, and prevent him from using overt automatic speech, we asked DPI to give the name of the month (or the day) that was between two others. For example, he was asked to tell the month between February and April or the middle month between February and June. Naming performance (100%) was significantly better with the 19 months and days than with the 19 pictures matched for length and frequency, $\chi^2(1) = 6.30$, $p < .01$.

Summary and discussion

Irrespective of the input modality (pictures, definitions, or incomplete sentences) or the output modality (oral or written), DPI was more accurate with verbs than with nouns. This holds even for homophonic verbs and nouns, showing that the difference is not due to phonological factors. As far as we can tell, adjectives follow the nominal pattern rather than the verbal one. This verb–noun dissociation has already been described in the literature, but when error detail is available, patients usually produce semantic paraphasias, verb nominalisations, circumlocutions, or omissions (Daniele et al., 1994; De Renzi & Di Pellegrino, 1995), suggesting a deficit in the semantic or lexical selection level. This contrasts sharply with DPI's performance; he was mainly impaired for word form retrieval.

Regarding the semantic categories, we found that the production of words in categories containing numerous exemplars (such as animals, artefacts, and vegetables) was as impaired as that of words in categories with few exemplars (body parts). This suggests that the "size" of the category is not critical for performance. DPI was perfect in numerals, months, and days, compared to other lexical categories. These three categories have in common the fact that they are learned through recitation. This, however, is not totally satisfactory: Performance was as good with a number like "mille" (*thousand*), which is not often used in automatic series of counting, as with "un" and "deux" (*one* and *two*), which more usually are. Hence, it could be that some property other than recitation ability accounts better for the good performance. Numerals and months are relatively abstract notions, at least compared to animals or body parts. Similarly, verbs tend to encode notions that are semantically quite abstract (see Gillette, Gleitman, Gleitman, & Lederer, 1999, for a discussion). Could it be that degree of concreteness accounts for DPI's overall pattern of results? We will investigate this issue in the next section.

The potential roles of concreteness

Dissociation between performance in concrete versus abstract items or in imageable versus non-imageable items is already known in aphasic patients (Breedin, Saffran, & Coslett, 1994; Franklin et al., 1995). Usually, patients are more accurate with concrete than with abstract words (Breedin et al., 1994; Franklin et al., 1995). This has been reported in various output modalities: in naming (Nickels & Howard, 1995), repetition impairment (Howard & Franklin, 1988), and oral reading (Coltheart, Patterson, & Marshall, 1988). However, verbs, numerals, months and days are not very imageable, and DPI's good performance in these items, if confirmed, may illustrate an unusual dissociation in an aphasic patient. Given that all these categories also differ from common names by their syntactic properties, the next experiments were designed to verify whether in DPI, syntactic variables and concreteness influence his performance independently. To remove the potential effect of syntactic category, the role of concreteness was first assessed only with nouns.

Definitions for matched abstract and concrete nouns

We selected 20 pairs of abstract-concrete nouns, for which members were matched in number of phonemes and syllabic structure (e.g., serment/serpent [sɛRmã]/[sɛRpã] (*sermon/snake)*). Half of them

Table 7. *Percentage of correct responses in production of abstract and concrete nouns (definition experiment)*

		Mean frequency	*% correct in 17 control subjects*	*% correct in DPI (2 examinations)*
Abstract	*N* = 20	35.9	90.6	45.0
Concrete	*N* = 20	37.5	94.4	20.0

were monosyllabic and half were bisyllabic. Concrete and abstract nouns were matched in frequency (see Table 7, and List C in the Appendix). For each noun a definition was constructed and presented orally. The list was run twice with DPI. Performance was better with abstract nouns (18/40) than with concrete nouns (8/40), $\chi^2(1) = 4.61$, $p < .03$. This contrasts with the performance of 17 control subjects run on this task. They were very accurate in general, but more so with concrete nouns (18.9/20 ± 0.93) than with abstract nouns (18.1/20 ± 0.99); $t(32) = 2.32$, $p = .027$.

Reanalysis of the noun–verb effect

The previous experiment confirms that DPI processes abstract nouns better than concrete nouns. Since he has been tested within a single syntactic category, this indicates that concreteness influences performance independently from syntax. We now ask whether DPI's good performance with verbs is related to their abstract character or whether the class as a whole is preserved. We know that verb–noun dissociations can hold even when controlling for concreteness (Baxter & Warrington, 1985; Caramazza & Hillis, 1991; De Renzi & Di Pellegrino, 1995; Rapp & Caramazza, 1998), but to the best of our knowledge, no such effect has been located at the level of word form retrieval. To check for potential concreteness effects in the verb–noun dissociation, we reanalysed the most critical experiment, namely the verb–noun homophone definitions (see Table 8). Twenty-one control subjects were asked to rate the concreteness of target nouns and verbs on a 5-point scale. Because concreteness is not very easy to define, we gave them "freedom" as an instance of score 1 and "tomato" as an instance of score 5. Overall, nouns were rated more concrete than the verbs (4.1 vs. 3.2), $t(21) = 3.60$, $p < .0001$. Then, we selected a subset of the 11 noun–verb homophonic pairs that were matched for concreteness (respectively 3.62 vs. 3.25), $t(10) = 1.2$, $p > .1$. In this subset, DPI's performance was still better with verbs than with nouns, $t(10) = 2.19$, $p < .05$. This suggests that concreteness cannot account for the noun-verb difference found above and that the two effects apply independently.

Table 8. *Reanalysis of the noun–verb homophone experiment*

Noun–verbs homophones	*N*	*Correct responses*	*Concreteness score*
All pairs			
Nouns	21	26.2%	4.10
Verbs	21	54.7%	3.20
Selected pairs matched for concreteness			
Nouns	11	30%	3.62
Verbs	11	50%	3.25

Discussion

Better performance with abstract nouns than with concrete nouns is a relatively infrequent finding. It has been reported in a case of dyslexia (Warrington, 1981) and in oral comprehension (Warrington, 1975, patient SBY; and Warrington & Shallice, 1984). However, to our knowledge, it is the first time such an effect has been reported in naming. The fact that abstract nouns are often impaired in production deficits was classically interpreted in terms of the richness of semantic features (Plaut & Shallice, 1993), concrete nouns having more features than superordinate or abstract nouns. In our case, however, such an explanation cannot hold, because it is the putatively semantically poorer nouns that are preserved relative to the richer ones. Our findings raise the possibility that abstract nouns constitute a lexical category separate from that of concrete nouns, rather than being defined in terms of a quantitative variable like number of features. Further research is needed to explore this hypothesis, and in particular, to explore whether abstract nouns might be further segregated along semantic domains (psychological terms, spatiotemporal terms, etc).

GENERAL DISCUSSION

Summary

We reported a patient with a naming impairment affecting word form retrieval. He produced mostly phonological paraphasias. Errors were largely governed by phonological variables like length and frequency. Conceptual knowledge, grammatical gender assignment, reading, and repetition were spared. Furthermore, naming errors were not uniform across semantic and syntactic domains. Concrete nouns were predominantly affected. Abstract nouns were significantly less affected, as were verbs. Numerals, months, and days were totally spared. This pattern of outcome supports the view that word form retrieval is organised along syntactic and semantic dimensions.

This result can be compared to the influence of syntactic and semantic variables reported in patients with semantic disorders or in anomic patients (see a review in Kremin, 1990). McCarthy and Warrington (1985) and Daniele et al. (1994) reported selective impairments of nouns or verbs in such patients. These deficits affected both comprehension and production, suggesting a category-specific deficit at the conceptual level. Others reported selective impairment of nouns or verbs in production, with intact comprehension (Baxter & Warrington, 1985; Berndt et al., 1997; Caramazza & Hillis, 1991; Damasio & Tranel, 1993; Hillis & Caramazza, 1995; Silveri & Di Betta, 1997), which suggests a deficit in lexical selection. Similarly, abstract and concrete nouns can be selectively affected in both comprehension and production in aphasic patients (Warrington, 1975, 1981). Anomic aphasia sometimes involves relative preservation of abstract nouns and/or verbs (see, for instance, Miceli, Giustolisi, & Caramazza, 1991), but impairments for concrete nouns are more frequently found in anomic aphasia (Kremin, 1990). Miozzo, Soardi, and Cappa (1994) reported the case of a pure anomic patient who is strikingly similar to our patient: action, colour, and number naming were spared, while body parts, vegetables, animals, and objects were impaired. However, as in the other studies mentioned here, the patient's response patterns are markedly different from DPI's: Patients either fail to produce a response, or produce circumlocutions or semantic paraphasias. Phonological paraphasias are, by contrast, very infrequent or nonexistent.

To our knowledge, only two papers have reported syntactic and/or semantic effects that can be located at the word form retrieval stage. Friederici and Shoenle (1980) described a patient who produced phonological errors that affected open-class words but not homophonic closed-class words. Cohen et al. (1997) reported a patient who made phonological errors in reading and naming, but no such errors with numerals.[6] As we noted in the Introduction, it is unclear whether the selective sparing should be defined semantically rather than in terms of syntactic category. In our study, we find an effect of both variables: an effect of syntactic class (nouns versus verbs) and an effect of concreteness for nouns. This is the first evidence that the organisation of word form storage is influenced by semantic and not only by syntactic variables.

Hence, the organisational principles that are typically relevant at the conceptual level may extend down to more peripheral levels such as word form retrieval. How do we interpret such results? We first discuss this question in terms of current processing models of speech production, and then in terms of anatomical segregation of functions.

[6] Baxter and Warrington (1985) reported a patient with phonological dysgraphia that affected more function words and verbs than nouns. However, the error pattern contained many real words, and/or derivational errors, and only very few phonemic/orthographic paraphasias. Hence, it is unclear whether the reported patient has a deficit at the word form retrieval stage or at the lexical selection stage.

Processing models

In this article, we have adopted a framework that distinguishes between two steps in production: lexical selection and word form retrieval. In these terms, our patient has a rather puzzling deficit, one that affects word form retrieval, but spares certain syntactic and semantic categories. Most processing models of speech production honour the lexical selection/word form retrieval distinction, but they do so in quite different ways. These differences could affect the interpretation of our results or signal further research directions. We restrict our discussion to three current models: Levelt et al. (1999), Caramazza (1997), and Foygel and Dell (2000).

In Levelt et al. (1999) (see Figure 4a), lexical selection corresponds to a process that, given a concept to be expressed, retrieves a *lemma*. Lemmas are grammatical representations of words which carry syntactic features and are used as a key to retrieve the word form. Word form retrieval in fact comprises two distinct steps: The first one, morphological encoding, maps a selected lemma onto a morphological representation (this corresponds to a level also called *lexeme,* Levelt, 1989). The second one, phonological encoding, is used to recover a phonological representation of the word form. The fact that our patient had excellent performance in gender decision, even with nouns that he could not name, militates in favour of an intact lexical selection process as well as an intact lemma. The impairment is located in further steps, although it is difficult to assess whether it concerns morphological encoding, phonological encoding, or both. This difficulty arises because French does not have a very rich morphological system, and hence it is not possible to devise tests that would distinguish between these two impairments. In any case, we can see linguistic reasons why a deficit around the morphological/lexeme level could, in principle, yield an interaction between phonological and grammatical variables. In many languages, clitics and affixes engage in class-specific phonological rules. For instance, the indefinite determiner "a" in English surfaces as [ə] or [ən] depending on the nature of the phoneme that starts the following word. Similarly, classes of English suffixes interact with the stress pattern of the word, while others do not. In English, nouns and verbs have different distributions of stress patterns, and these differences are used by speakers of this language (Kelly, 1992). One could then propose that the morphological/lexeme level is functionally organised in terms of the syntactic categories that interact with phonological processes. However, in the particular case of French nouns and verbs, it is not clear which phonological rule or regularity would justify the separation of these two classes within word form retrieval. This scepticism should apply even more to the concreteness effect. Indeed, concreteness is not a linguistically defined notion. Rather, it is an operationally defined notion depending on participants' intuitions.[7] In brief, on purely linguistic grounds, it is difficult to motivate a noun/verb or concrete/abstract distinctions at the morphological/lexeme level in our patient. Hence, within Levelt's model, there is no linguistic or processing motivation for postulating that word form retrieval is grammatically and semantically organised, when the language does not use such distinctions in actual phonological rules. Of course, there could be anatomical motivations for such an organisation, as we discuss below.

Caramazza's (1977) framework is presented in terms of a connectionist architecture (Figure 4b). Yet, we can distinguish representations (the nodes) and processes (the spread of activation within the links). Interpreted in these terms, lexical selection is the process that starts with the activation of features in the lexical-semantic network and yields the activation of units in the lexeme network. Note that a direct connection may also be posited between the lexical-semantic network and the syntactic network. In brief, lexical selection selects lexemes, not lemmas. Lemmas are totally absent in Caramazza's model. Lexemes are then used to recover syntactic

[7] For verbs, compositional theories of verb meaning (Jackendoff, 1990; Pinker, 1989) have been used to propose a distinction between semantically simple (or light) and semantically complex (or heavy) verbs (see Berndt et al., 1997; Breedin et al., 1998), but for nouns, the prospects of a linguistic definition of concreteness are unclear.

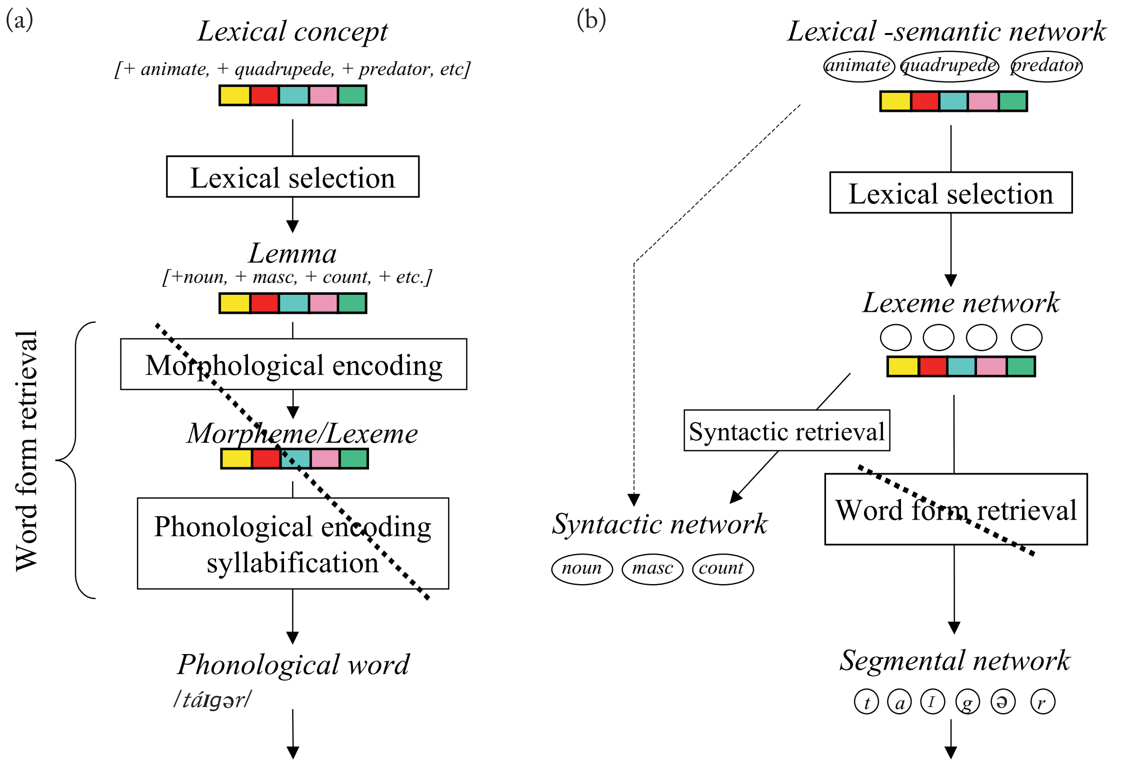


Figure 4. *Interpretetation of DPI's deficit in two alternative models of speech production. (a) Represents a model inspired by Levelt et al. (adapted from Levelt, Roelofs, & Meyer, 1999). (b) Represents a model inspired by Caramazza (adapted from Caramazza, 1997). In both panels, processes are displayed within boxes, and representations are shown in italics. Squares with shaded grey designate parts of the models that have a functional segregation along syntactic and semantic dimensions. Processes that are impaired in the patient are crossed with dotted lines.*

information in the syntactic nodes (syntactic retrieval) and, in parallel, phonological information (word form retrieval). In this model, the lexeme level is a sort of hub that interconnects three systems: conceptual, phonological, and syntactic. It would not be absurd to posit that its functional organisation reflects variables that are relevant to all of these three systems. So, given that the conceptual system honours a concrete/abstract distinction, the grammatical system honours a noun/verb distinction, and the phonological system cares about length and frequency, perhaps the lexeme level is organised in terms of all of these variables (or perhaps, a blurred correlate of these variables). According to this assumption, a local lesion to the output pathway towards the phonological planning system could spare certain semantically or syntactically defined regions of the lexicon. Although such a proposition would have to be more fully specified, it actually makes a rather interesting prediction: One should be able to observe homologous impairments and sparing in lexical selection deficits and word form retrieval deficits. For instance, patients with semantic category-specific deficits (animals, vegetables, artefacts) in word form retrieval should be observed. Vice versa, patients with frequency or length-governed deficits in lexical selection should also be found. It remains to be seen whether such predicted patterns of results can be observed in patients.

In Foygel and Dell 's (2000) model, the key notion is that of interactive activation (see also Dell, 1985). Unlike the discrete sequential models (Levelt, 1989), in this model multiple lexical items can be activated to various degrees, and partial activation can cascade up and down to other levels. Within such connectionist architectures, the relationship between lesion site and deficit type is hence more complicated to establish than in discrete models. For instance, Dell, Schwartz, Martin, Saffran, and Gagnon (1997) used a two-step architecture similar to that depicted in Figure 4b (semantic-to-lexical links and lexical-to-phonology links), and showed that altering parameters such as connection strength or decay rate in a global way can produce a wide variety of error patterns, ranging from semantic to phonological paraphasias. Foygel and Dell argue that although global deficits can capture a substantial range of aphasic types, they have more difficulty in dealing with extreme cases of dissociation (pure semantic errors or pure phonological errors). Instead, they argue that such cases are better captured with more local deficits, such as lesions of the semantic-to-lexical or lexical-to-phonology links. Our patient is probably of this last type. Indeed, DPI's preserved ability to find the gender of words that he could not name suggests that the semantic weights are preserved.[8] Therefore, we are left with two possibilities to explain the effect of syntactic and semantic variables in DPI. The first possibility is that our patient has a small semantic deficit in addition to his phonological impairment. This deficit would affect concrete nouns but not abstract nouns or verbs. It would have to be small enough not to yield any visible impairment in semantic tasks or in gender assignment tasks, but large enough to increase substantially the rate of phonological errors. In principle, connectionist architectures incorporate nonlinear mechanisms that can generate super-additive effects, and turn a subclinical deficit into an observable deficit at another processing level. Whether such an outcome can be numerically obtained in a network simulation remains to be established. Such an interpretation is bound to the prediction that more precise measures, such as reaction times, should reveal a semantic deficit for concrete nouns in our patient. A second possibility would be that the lexical level is itself topographically organised in terms of semantic and syntactic dimensions, just as in the above discussion of Caramazza's model. Here again, a geographically restricted lesion to the lexical-to-phonology links could produce the observed deficit pattern.

In brief, we have shown that our results have important implications for three recent versions of a two-step theory of word production. They suggest that models either have to postulate complex interaction between processing levels (such as subclinical deficits interacting with more observable ones), or they have to incorporate syntactic and semantic functional segregation at a lower level than is usual. In particular, we raised the possibility that the same kind of category-specific dissociations that have been documented in semantic deficits might be found in word form retrieval deficits.

Anatomical perspective

Before closing, we would like to address our findings from a neuroanatomical perspective. There is growing evidence that the lexico/semantic system is distributed in a network of perisylvian areas within which different conceptual and syntactic classes are sustained by partially overlapping and partially distinct subsystems. Many studies point to inferior frontal (impaired in Broca's aphasia) and parieto-temporal processes in verbs and to occipito-temporal processes (impaired in Wernicke's or anomic aphasia) in nouns. Such a segregation was reported in brain-lesioned patients (Berndt et al., 1997; Breedin & Martin, 1996; Breedin, Saffran, & Schwartz, 1998; A. R. Damasio & Tranel, 1993; Daniele et al., 1994; Hillis & Caramazza, 1995; Miceli et al., 1988), in EEG (Pulvermuller, Preissl, Lutzenberger, & Birbaumer, 1996) and PET studies (Wharburton et al., 1996; see Baxter & Warrington, 1985; Caramazza & Hillis, 1991; De Renzi & Di Pellegrino, 1995, for exceptions to this pattern). Within the noun category, there is evidence that the temporal area is further segregated as a function of semantic categories, with animals involving more occipital-temporal regions, and inanimate

[8] The gender of most French nouns, except the ones that refer to humans, is unpredictable based on semantic information.

objects, especially tools, involving more parietal-temporal regions, in addition to frontal regions (H. Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996; Humphreys & Forde, 2000). Anatomical segregation is less clear with respect to the distinction between abstract and concrete nouns (Baxter & Warrington, 1985; Berndt et al., 1997; Caramazza & Hillis, 1991; De Renzi & Di Pellegrino, 1995; Friederici, Opitz, & Von Cramon, 2000; Kansaku et al., 1998; Kiehl et al., 1999; Warrington, 1981). For instance, patient DRB with a left middle cerebral infact (Franklin et al., 1995) had difficulties in abstract word comprehension. In contrast, CAV (Warrington, 1981) and SBY (Warrington & Shallice, 1984) had a significant impairment in their ability to read or comprehend concrete words compared with abstract words, but had also a lesion involving at least the left temporal lobe. As we discussed above, it could be that the class of abstract nouns is not homogeneous and that more fine-grained distinctions are needed to draw a clearer picture. For instance, many of our abstract words referred to emotional or theory of mind concepts, which may involve, among others, frontal areas. Other abstract words referring to mathematical or temporal entities may involve more parietal areas. More research is needed to examine these distinctions.

Putting aside the discrepancies in the anatomical segregation among some of these categories, one could speculate that these distributed systems preserve some of their organisation when they project onto the word form lexicon, which many authors locate in the posterior part of the temporal lobe. As proposed by Tranel, Damasio, and Damasio (1997a), and Tranel, Logan, Frank, and Damasio (1997b), the processing of words may involve convergence/divergence zones that are located anatomically close to the areas that process the conceptual/perceptual/functional salient properties of these words. For instance, the lexical processing of verbs may involve convergence zones linked to networks representing body motion; lexical processing of imageable nouns might involve convergence zones closer to the regions involved in object identification. According to these authors, these zones are not defined categorically, but depend on the relative weight of the relevant functional/perceptual cues. Moreover, lexical factors such as complexity or familiarity can also influence the organisation of these convergence zones (see Kemmerer & Tranel, 2000).

Using the terminology of Damasio and his colleagues, our results suggest that convergence zones are involved not only in the conceptual and lexical representations of words, but also in their phonological representations. This may seem a surprising claim, but less so when considered within a developmental perspective. Assuming that the production system is established in childhood, starting from the higher levels downwards to the more peripheral levels, one might envision that part of the initial topography is relatively preserved and reproduced in the downwards projections (if the word form system is a downward projection of the conceptual system). This might account for the presence of a semantic segregation at the word form level, even though it has no clear linguistic or processing advantage.

Concluding remarks

We have provided converging evidence collected from patient DPI in support of the view that semantic and syntactic variables influence purely phonological processing levels such as word form retrieval. (Of course, we are aware of the fact that such a conclusion is in need of more evidence.) Additional evidence might be sought from anomic patients, who, as we noted above, often display sensitivity to conceptual (abstract/concrete) and syntactic (noun/verb) dimensions in much the same way as we found in DPI. Anomia is a deficit that is typically interpreted as damage either of the conceptual system or of lexical selection. However, this is not the only possibility, as severe damage to word form retrieval could potentially lead to anomic behaviour. For instance, Kay and Ellis (1987) claim that EST, an anomic patient, has a problem with word form retrieval rather than with lexical selection. Indeed, like DPI, he was able to provide phonological information about target words, as in the "tip of the tongue" state . In other words, it is possible that some of the reported anomic aphasic cases in the literature also suffer from a problem in word form retrieval, but that a more severe deficit could mask such an aetiology. A closer look at such patients could help us to understand in more detail the role of syntactic and semantic variables in word form retrieval.

Manuscript received 19 December 2001
Revised manuscript received 29 November 2002
Revised manuscript accepted 29 November 2002

REFERENCES

Bachoud-Lévi, A.-C., Dupoux, E., Cohen, L., & Mehler, J. (1998). Where is the length effect? A cross-linguistic study of speech production. *Journal of Memory and Language*, *39,* 331–346.

Baxter, D. E., & Warrington, E. K. (1985). Category-specific phonological dysgraphia. *Neuropsychologia*, *23,* 653–666.

Benson, D. F. (1979). Neurologic correlates of anomia. In H. Whitaker & H. A. Whitaker (Eds.), *Studies in neurolinguistics* (pp. 293–328). New York: Academic Press.

Berndt, R. S., Mitchum, C. S., Haendiges, A. N., & Sanson, J. (1997). Verb retrieval in aphasia. Characterizing single word impairments. *Brain and Language*, *56*, 68–106.

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

Breedin, S. D., Saffran, E. M., & Coslett, H. B. (1994). Reversal of the concreteness effect in a patient with semantic dementia. *Cognitive Neuropsychology*, *11*, 617–660.

Breedin, S. D., Saffran, E. S., & Schwartz, M. F. (1998). Semantic factors in verb retrieval: An effect of complexity. *Brain and Language*, *63,* 1–31.

Brown, R., & McNeill, D. (1966). The "tip of the tongue" phenomenon. *Journal of Verbal Learning and Verbal Behavior*, *5,* 325–337.

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

Butterworth, B. (1980). Some constraints on models of language production. In B. Butterworth (Ed.), *Language production: Speech and talk* (pp. 423–459). San Diego, CA: Academic Press.

Butterworth, B. (1989). Lexical access in speech production. In W. Marslen-Wilson (Ed.), *Lexical representation and process* (pp. 108–135). Cambridge, MA: MIT Press.

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

Caramazza, A., & Hillis, A. E. (1991). Lexical organization of nouns and verbs in brain. *Nature*, *349,* 788–790.

Caramazza, A., & Shelton, J. R. (1998). Domain-specific knowledge systems in the brain: The animate-inanimate distinction. *Journal of Cognitive Neuroscience*, *10,* 1–34.

Cohen, L., Verstichel, P., & Dehaene, S. (1997). Neologistic jargon sparing numbers: A category-specific phonological impairment. *Cognitive Neuropsychology*, *14,* 1029–1061.

Coltheart, M., Patterson, K. E., & Marshall, J. C. (1988). *Deep dyslexia*. London: Routledge & Kegan Paul.

Content, A., Mousty, P., & Radeau, M. (1990). Brulex, une base de données lexicales informatisée pour le français écrit et parlé. *L'Année Psychologique*, *90,* 551–566.

Coslett, H. B., Gonzalez-Royhi, L. G., & Heilman, K. M. (1984). Reading: Selective sparing of closed-class words in Wernicke aphasia. *Neurology*, *34,* 1038–1045.

Damasio, A. R., & Tranel, D. (1993). Nouns and verbs are retrieved with differentially distributed neural systems. *Proceedings of the National Academy of Science*, *90,* 4957–4960.

Damasio, H., Grabowski, T. J., Tranel, D., Hichwa, R. D., & Damasio, A. R. (1996). A neural basis for lexical retrieval. *Nature*, *380,* 499–505.

Daniele, A., Guistolisi, L., Silveri, C., Colosimo, C., & Gainotti, G. (1994). Evidence for a possible neuro-anatomical basis for lexical processing of nouns and verbs. *Neuropsychologia*, *32,* 1325–1341.

Dehaene, S. (1995). Electrophysiological evidence for category-specific word processing in the normal human brain. *Neuroreport*, *6,* 2153–2157.

Dehaene, S. (1997). *The number sense: How the mind creates mathematics.* New York: Oxford University Press.

Dell, G. S. (1985). Positive feedback in hierarchical connectionist models: Applications to language production. *Cognitive Science*, *9,* 3–23.

Dell, G. S. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review*, *93,* 283–321.

Dell, G. S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of Memory and Language*, *27,* 124–142.

Dell, G. S., & O'Seaghdha, P. G. (1992). Stages of lexical access in language production. *Cognition*, *42,* 287–314.

Dell, G. S., & Reich, P. A. (1981). Stages in sentence production: An analysis of speech error data. *Journal of Verbal Learning and Verbal Behavior*, *20,* 611–629.

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review*, *104,* 801–838.

De Renzi, E., & Di Pellegrino, G. (1995). Sparing verbs and preserved but ineffectual reading in patient with impaired word production. *Cortex*, *31,* 619–636.

Eriksen, C. W., Pollock, M. D., & Montague, W. E. (1970). Implicit speech: Mechanisms in perceptual encoding? *Journal of Experimental Psychology*, *84,* 502–507.

Farah, M. J., Hammond, K. M., Mehta, Z., & Ratcliff, G. (1989). Category-specificity and modality-specificity in semantic memory. *Neuropsychologia*, *27,* 193–200.

Fay, D., & Cutler, A. (1977). Malapropisms and the structure of the mental lexicon. *Linguistic Inquiry*, *8,* 505–520.

Fodor, J. A., Garrett, M. F., Walker, E. C., & Parkes, C. H. (1980). Against definitions. *Cognition*, *8,* 263–267.

Foygel, D., & Dell, G. S. (2000). Models of impaired lexical access in speech production. *Journal of Memory and Language*. *43*, 182–216.

Franklin, S., Howard, D., & Patterson, K. (1995). Abstract word anomia. *Cognitive Neuropsychology*, *12,* 549–566.

Friederici, A. D., Opitz, B., & von Cramon, D. Y. (2000). Segregating semantic and syntactic aspects of processing in the human brain: An fMRI investigation of different word types. *Cerebral Cortex*, *10*(7), 698–705.

Friederici, A. D., & Shoenle, P. W. (1980). Computational dissociation of two vocabulary types: Evidence from aphasia. *Neuropsychologia*, *18,* 11–20.

Garrett, M. F. (1975). The analysis of sentence production. In G. Bower (Ed.), *The psychology of learning and motivation*. New York: Academic Press.

Garrett, M. (1992). Disorders of lexical selection. *Cognition*, *42,* 143–180.

Gillette, J., Gleitman, H., Gleitman, L., & Lederer, A. (1999). Human simulations of vocabulary learning. *Cognition*, *73,* 135–176.

Goodglass, H., & Kaplan, E. (1983). *Boston Naming Test*, Philadelphia: Lea & Febiger.

Goodglass, H., Klein, B., Carey, P., & Jones, K. (1966). Specific semantic word categories in aphasia. *Cortex*, *2,* 74–89.

Hart, J., Berndt, R. S., & Caramazza, A. (1985). Category-specific naming deficit following cerebral infarction. *Nature*, *316,* 439–440.

Hillis, A. E., & Caramazza, A. (1991). Category-specific naming and comprehension impairement: A double dissociation. *Brain*, *114,* 2081–2094.

Hillis, A. E., & Caramazza, A. (1995). Representation of grammatical categories of words in the brain. *Journal of Cognitive Neuroscience*, *7,* 396–407.

Hillis, A. E., Rapp, B. C., & Caramazza, A. (1999). When a rose is a rose in speaking but a tulip in writing. *Cortex*, *35*, 337–356.

Howard, D., & Franklin, S. (1988). *Dissociations between component mechanisms in short-term memory: Evidence from brain-damaged patients*. Cambridge, MA: MIT Press.

Humphreys, G. W., & Forde, E. M. E. (2001). Hierarchies, similarity and interactivity in object recognition: On the multiplicity of "category-specific" deficits in neuropsychological populations. *Behavioural and Brain Sciences*, *24*, 453–476.

Jackendoff, R. (1990). *Semantic structures*. Cambridge, MA: MIT Press.

Jescheniak, J. D., & Levelt, W. J. M. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20,* 824–843.

Kansaku, K., Shimoyama, I., Nakajima, Y., Higuchi, Y., Nakazaki, S., Kubota, M., Morita, F., Kusaka, T., Katoh, K., & Yamaura, A. (1998). Functional magnetic resonance imaging during recognition of written words: Chinese characters for concrete objects versus abstract concepts. *Neuroscience Research*, *30*(4), 361–364.

Kay, J., & Ellis, A. W. (1987). A cognitive neuropsychological study of anomia: Implications for psychological models of word retrieval. *Brain*, *110,* 613–629.

Kelly, M. H. (1992). Using sound to solve syntactic problems: The role of phonology in grammatical category assignments. *Psychological Review*, *99,* 349–364.

Kemmerer, D., & Tranel, D. (2000). Verb retrieval in brain-damaged subjects: 1. Analysis of stimulus, lexical, and conceptual factors. *Brain and Language*, *73*, 347–392.

Kiehl, K. A., Liddle, P. F., Smith, A. M., Mendrek, A., Forster, B. B., & Hare, R. D. (1999). Neural pathways involved in the processing of concrete and abstract words. *Human Brain Mapping*, *7*(4), 225–233.

Klapp, S. T., Anderson, W. G., & Berrian, R. W. (1973). Implicit speech in reading, reconsidered. *Journal of Experimental Psychology*, *100,* 368–374.

Kremin, H. (1990). Naming and its disorders. In H. Goodglass (Ed.), *Handbook of neuropsychology* (pp. 307–328). Amsterdam: Elsevier.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.

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

Manning, L., & Warrington, E. K. (1996). Two routes to naming: A case study. *Neuropsychologia*, *34,* 809–817.

Mazaux, J. M., & Orgogozo, J. M. (1982). *Echelle d'évaluation de l'aphasie: Adaptation française du Boston Diagnostic Aphasia Examination*. Issy-les-Moulineaux, France: Editions Scientifiques et Psychologiques.

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

McClelland, J. L. (1979). On the time relations of mental processes: An examination of systems of processes in cascade. *Psychological Review*, *88,* 375–407.

Miceli, G., Giustolisi, L., & Caramazza, A. (1991). The interaction of lexical and nonlexical processing mechanisms: Evidence from anomia. *Cortex*, *27,* 57–80.

Miceli, G., Silveri, M. C., Nocentini, U., & Caramazza, A. (1988). Patterns of dissociation in comprehension and production of nouns and verbs. *Aphasiology*, *2,* 351–358.

Miceli, G., Silveri, M. C., Villa, G., & Caramazza, A. (1984). On the basis for the agrammatic's difficulty in producing main verbs. *Cortex*, *20,* 207–220.

Miozzo, A., Soardi, M., & Cappa, S. F. (1994). Pure anomia with spared action naming due to a left temporal lesion. *Neuropsychologia*, *32,* 1101–1109.

Nickels, L., & Howard, D. (1995). Aphasic naming: What matters? *Neuropsychologia*, *33,* 1281–1303.

Pinker, S. (1989). *Learnability and cognition: The acuisition of argument structure*. Cambridge, MA: The MIT Press.

Plaut, D. C., & Shallice, T. (1993). Deep dyslexia: A case study of connectionist neuropsychology. *Cognitive Neuropsychology*, *10,* 377–500.

Pulvermuller, F., Preissl, H., Lutzenberger, W., & Birbaumer, N. (1996). Brain rhythms of language: nouns versus verbs. *European Journal of Neuroscience*, *8,* 937–941.

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

Shattuck-Hufnagel, S. (1979). Speech errors as evidence for a serial ordering mechanism in sentence production. In L. E. Associates (Ed.), *Sentence processing: Psycholinguistic studies presented to Merill Garrett* (pp. 295–342). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Shattuck-Hufnagel, S. (1992). The role of the word structure in segmental serial encoding. *Cognition*, *42,* 213–259.

Silveri, M. C., & Di Betta, A. M. (1997). Noun–verb dissociations in brain-damaged patients: further evidence. *Neurocase*, *3,* 477–488.

Tranel, D., Damasio, H., & Damasio, A. R. (1997a). A neural basis for the retrieval of conceptual knowledge. *Neuropsychologia*, *35*, 1319–1327.

Tranel, D., Logan, C. G., Frank, R. J., & Damasio, A.R. (1997b). Explaining category-related effects in the retrieval of conceptual and lexical knowledge for concrete entities: Operationalization and analysis of factors. *Neuropsychologia*, *35*, 1329–1339.

Warrington, E. K. (1975). The selective impairment of semantic memory. *Quarterly Journal of Experimental Psychology*, *27,* 635–657.

Warrington, E. K. (1981). Concrete word dyslexia. *British Journal of Psychology*, *72,* 175–196.

Warrington, E. K., & Shallice, T. (1984). Category-specific semantic impairment. *Brain*, *107,* 829–854.

Wharburton, E., Wise, R. J. S., Price, C. J., Weiller, C., Hadar, U., Ramsay, S., & Frackowiak, R. S. J. (1996). Noun and verb retrieval by normal subjects. Studies with PET. *Brain*, *119,* 159–179.

Zingeser, L. B., & Berndt, R. S. (1990). Retrieval of nouns and verbs in aggrammatism and anomia. *Brain and Language*, *39,* 14–32.

APPENDIX

List A: Words and nonwords (repetition, auditory word matching)

Monosyllables		*Frequency/No. of neighbours*[a]	*Bisyllables*		*Frequency/No. of neighbours*
		Low-frequency words			
lionne	(lion [fem])	25	mygale	(trapdoor spider)	21
couette	(duvet)	38	macaque	(macaque)	46
faon	(dawn)	72	pipeau	(reed pipe)	51
buse	(buzzard)	80	rabot	(plane)	55
dîme	(tithe)	102	mulot	(field mouse)	59
manne	(manna)	119	combine	(trick)	59
pouf	(pouf)	136	puma	(puma)	80
lime	(file)	157	bidet	(bidet)	93
louve	(wolf [fem])	178	bison	(buffalo)	97
limbes	(limb)	268	bévue	(blunder)	110
phoque	(seal)	289	séquelle	(aftermath)	114
pince	(pliers)	348	morue	(cod)	148
fraude	(fraud)	361	chaloupe	(launch)	153
taupe	(mole)	365	chacal	(jackal)	165
crabe	(crab)	395	gâchis	(slush)	178
guêpe	(wasp)	425	dindon	(turkey [masc])	204
		High-frequency words			
singe	(monkey)	1646	canard	(duck)	1297
lion	(lion)	1791	pigeon	(pigeon)	1310
phase	(phase)	1812	pendule	(pendulum)	1540
coq	(roster)	1842	divan	(couch)	1646
règne	(kingdom)	2029	cochon	(pig)	1791
jupe	(skirt)	2207	magie	(magic)	1863
voûte	(arch)	2254	lapin	(rabbit)	2012
puits	(well)	2373	wagon	(carriage)	2144
bœuf	(beef)	2650	manie	(habit)	2156
vœu	(wish)	2820	serpent	(snake)	2190
caisse	(case)	2888	mouton	(sheep)	2237
mouche	(fly)	3373	bâton	(stick)	2390
vache	(cow)	3526	taureau	(bull)	3143
chat	(cat)	4326	méthode	(method)	8168
choix	(choice)	7551	départ	(departure)	11754
chien	(dog)	12112	cheval	(horse)	13507
		Nonwords			
psu	/psy/	0	gonvi	/gõvi/	0
teuve	/tœv/	0	moupin	/mupɛ̃/	0
nuon	/nɥõ/	0	dinru	/deru/	0
gline	/glin/	0	banoume	/banum/	0
zanze	/zãz/	0	sopar	/sopar/	0
zonfe	/zõf/	0	bira	/bira/	0
pioube	/pjub/	0	pezou	/pezu/	0
teugue	/tœv/	0	picaque	/pikak/	0
bube	/byb/	10	balaj	/balaʒ/	8
cripe	/krip/	11	banar	/banar/	10
guipe	/gip/	11	katal	/katal/	11
graiche	/grɛʃ/	12	bouguet	/buge/	14
drai	/drɛ/	15	charet	/ʃare/	14
daine	/dɛn/	23	paton	/patõ/	14
zoua	/zwa/	25	gouchet	/guʃe/	15
jal	/ʒal/	30	kavet	/kave/	23

[a]For words, frequency is computed per 100 million (Content, Mousty, & Radeau, 1990); for nonwords, neighbours are computed as the number of words differing by one phoneme.

List B: Verb/noun homophones

1. un bois (a wood), il boit (he drinks)	12. une louche (a ladle), il louche (he squints)
2. une boite (a box), il boite (he limps)	13. une marche (a step), il marche (he walks)
3. une coupe (a cup), il coupe (he cuts)	14. un marché (a market), marcher (to walk)
4. une cour (a court), il cours (he runs)	15. une montre (a watch), il montre (he shows)
5. une croix (a cross), il croit (he believes)	16. un pouce (a thumb), il pousse (he pushes)
6. un cri (a shout) il crie (he shouts)	17. une porte (a door), il porte (he carries)
7. une danse (a danse), il danse (he dances)	18. un prix (a price), il prie (he prays)
8. un devoir (a homework), devoir (to ought to)	19. une salle (a room), il sale (he salts)
9. un fait (a fact), il fait (he does)	20. un ski (ski), il skie (he skis)
10. une ferme (a farm), il ferme (he closes)	21. la vie (life), il vit (he saw)
11. un lit (a bed), il lit (he reads)	22. un vœu (a wish) il veut (he wants)

List C: Concrete/abstract words

	Abstract nouns			*Concrete nouns*		
Structure	*Item*		*Frequency*[a]	*Item*		*Frequency*[a]
CV	paix	(peace)	16196	lit	(bed)	20416
CVC	tante	(aunt)	6139	chaise	(chair)	8168
CVC	messe	(mass)	4649	chaîne	(chain)	4050
CVC	paire	(pair)	1578	bague	(ring)	1178
CVC	dette	(debt)	1574	beurre	(butter)	1335
CVC	panne	(engine failure)	680	selle	(saddle)	795
CVC	honte	(shame)	9236	hanche	(hip)	1501
CVY	deuil	(mourning)	2535	feuille	(leave)	10265
CVY	bail	(lease)	246	quille	(skittle)	480
CVCC	perte	(loss)	4173	barbe	(beard)	4203
CVCV	santé	(health)	6147	foret	(forest)	7823
CVCV	salut	(salutation)	6500	rideau	(curtain)	5862
CVCVC	retard	(delay)	4530	cheval	(horse)	13507
CVCVC	semaine	(week)	15626	montagne	(mountain)	10129
CVCCVC	vertige	(vertigo)	2650	journal	(newspaper)	20854
CVCCVC	discours	(discourse)	8602	casquette	(cap)	1484
CVCCV	serment	(pledge)	1535	serpent	(snake)	2190
CVCCV	respect	(respect)	6483	jardin	(garden)	14975
VCCVC	organe	(organ)	4458	horloge	(clock)	1386
VCVC	usure	(wear)	884	éponge	(sponge)	638

[a]Frequency per 100 million in the French database (Content et al., 1990).