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CLOSED-CLASS WORDS IN SENTENCE PRODUCTION: EVIDENCE FROM A MODALITY-SPECIFIC DISSOCIATION

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Classic observations in the field of the neuropsychology of language have established that brain injury can result in the specific disruption of the ability to use words from the closed class (e.g., determiners, auxiliary verbs, prepositions, etc.) while the production of words from the open class is preserved (e.g., nouns, verbs, etc.). In this study, we report the case of a French native speaker who, following a cerebral-vascular accident, presents a dissociation between open- and closed-class words. Importantly, this dissociation is only observed in the written modality of output while oral speech production is by and large normal. Furthermore, the difficulties in writing closed-class words were only observed during sentence production—in spontaneous production or in writing to dictation tasks—but not during single word production. The origin of this deficit is discussed in the context of previously proposed models of sentence production.

INTRODUCTION

Language production is generally modelled by postulating three types of processes: conceptualisation, formulation, and overt execution (Bock & Levelt, 1994; Levelt, 1989). During conceptualisation a message and a communicative intention are constructed. Processing at this level is thought to involve "pre-linguistic" representations. Formulation refers to the stage during which the words that convey the intended message are selected and encoded into well-formed sequences. Finally, overt execution refers to the peripheral stage of articulation, in the case of oral production, or hand movement execution, in the case of written production. In this article, we are interested in the description of the formulation stage in the context of psycholinguistic and neurolinguistic models of sentence production (e.g., Garrett, 1975, 1982, 1984). We report the case of a native speaker of French who, following a stroke, presented dissociated problems in writing. This patient made a significantly large number of errors with closed-class words when writing (see below). By contrast his oral production was by and large normal. Our experimental investigation indicates the conditions in which closed-class word retrieval was impaired. The patient made errors only in sentence production tasks (e.g., spontaneous production, writing to dictation), but not when writing words in isolation

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or in unrelated lists. As we will show, the restricted character of this deficit is relevant for understanding the processes of closed-class word selection and sentence construction.

In this Introduction, we begin by providing a general overview of the seminal model proposed by Garrett (1975, 1982, 1984) to account for the processes of oral sentence production. We then focus on the differences postulated in that model, as well as in many accounts of language production, between the processes that are responsible for the production of open- and closed-class words. The section includes a review of a number of observations that motivate such a distinction. Finally, we discuss how Garrett's model of oral production can be extended to account for written production, an extension that is important to us since the patient we report presents a deficit that selectively affects written production.

A model of sentence production

The main theoretical background for the case study reported here is Garrett's model of sentence production (Garrett, 1975, 1982, 1984; see also Bock & Levelt, 1994). This model, originally designed to account for the process of sentence production in normal speakers, is based on the analysis of slips of the tongue produced by normal speakers. Garrett's seminal proposal has also been used as a common framework for research investigating normal and aphasic sentence production (e.g., Berndt, 2001). This model of sentence encoding comprises two major hypotheses. First, the process of formulation—during which lexical items are selected and encoded—is divided into two processing levels: the *functional* and the *positional* levels. This distinction is largely accepted. Second, the model hypothesises that there are important differences between the retrieval of open-class words (e.g., nouns, verbs, adjectives, etc.) and the processing of closed-class words (e.g., determiners, prepositions, conjunctions, etc.) More specifically, the representation of closed-class words is closely tied to the representation of sentence frames (something that is not the case for open-class words).

Let us consider first the organisation of the formulation process. During functional processing, lexical selection for open-class words is carried out. At this level, open-class words are generally represented by a modality-neutral lexical representation—the lemma (see below for an alternative representation of open-class items). Lemmas code the grammatical properties of lexical items (e.g., Garrett, 1988; Kempen & Huijbers, 1983; Levelt, Roelofs, & Meyer, 1999; but see Caramazza, 1997; Starreveld & La Heij, 1996). After selection, these items are organised in a structure that establishes relations between them by the attribution of grammatical and/or thematic roles. Two characteristics of the functional level are relevant for us. First, this level of processing involves abstract lexical representations but no phonological information. Second, only open-class words are retrieved at this level; information regarding closed-class words is not processed until the following positional level. Note, however, that there is an important exception in the closed-class set: prepositions. The pattern of errors in which some prepositions are involved lies somewhat between that of open-class and closed-class items (e.g., they can be involved in word exchanges, but most often not in phonological errors; see below a discussion of error patterns). Therefore, prepositions are given a special status in the model. They are retrieved at the functional level, like open-class words (and they are processed like closed-class words at the positional level; see also Bock, 1989).

The second level of processing during sentence encoding, the positional level, involves sentence "positional frames" and the phonological representation of open-class words (generally called *lexemes* in single-word production models). Sentence frames are syntactic—therefore presumably amodal—representations of the surface phrase geometry. They are retrieved/constructed during this stage. These frames comprise positional slots in which the lexemes corresponding to the previously selected open-class lemmas will be inserted. Note that some single-word models do not postulate two levels of lexical processing (the lemma-lexeme distinction), but only one (Caramazza, 1997; Starreveld & La Heij, 1996). In this view, lexical access involves the selection of phonological (or orthographic) lexemes directly on the basis of information at the message level. In general, these models have not been explicitly developed to account for sentence processing although they could possibly be adapted to do so (see discussion in Berndt & Haendiges, 2000).

Besides positional slots in which to insert open-class items, positional frames also comprise information about closed-class items. In fact, the representation of closed-class words is intimately tied to the frame. Garrett proposed that the surface phrasal frame "bears inflectional elements and minor category free forms" (that is, closed-class words; Garrett, 1982, p. 50).[1] The hypothesis put forward by Garrett is the following: closed-class elements are features of positional frames that do not have to be retrieved (as open-class items are selected and retrieved) other than by retrieving the frame. Furthermore, the segmental structure of these elements is not fixed "until a point following the lexical interpretation of the positional string" (that is, the insertion of the lexemes in the sentence frames; Garrett, 1982, p. 62).

In short, then, Garrett's model of sentence construction comprises two main processing steps. At the functional level, a grammatical representation of the open-class items (lemmas) and prepositions used in the sentence is retrieved. These items are attributed thematic and/or syntactic roles. Subsequently, at the positional processing level, sentence frames are retrieved. These frames include slots (in which the forms of open-class words, lexemes, are inserted) as well as feature information about closed-class items (including prepositions). The output of the positional stage is a surface phonological representation of the sentence in which the forms of closed-class items remain to be specified. This output of the positional processing is used as input to the phonetic and articulatory output processes.

Empirical observations that distinguish the processing of open- and closed-class words

In this section, we review some of the major findings that have been used to characterise the processes of sentence production, paying a special attention to the distinction between open- and closed-class word processing. As noted previously, the open class comprises nouns, verbs, adjectives and some adverbs; the closed class comprises determiners, prepositions, auxiliary verbs, conjunctions, etc. Open-class words serve (primarily) to convey the intended message, whereas closed-class words serve (primarily) to convey sentential structure in word sequences (see Bird, Franklin, & Howard, 2002, for a detailed presentation). Open-class words are generally selected on the basis of the message that is to be expressed, whereas closed-class word selection can also be based on linguistic information, for example, when word selection involves agreement rules (e.g., during determiner production; see Caramazza, Miozzo, Costa, Schiller, & Alario, 2001). Besides these descriptive differences, the distinction between open- and closed-class words is reflected in the actual performance of normal and aphasic speakers. Speech production errors—slips of the tongue—produced by healthy speakers are more likely to occur on open-class words than on closed-class words and the types of errors affecting the two types of words are different. Open-class items are likely to be involved in word substitutions, whereas closed-class words are more often lost or added than involved in substitutions or exchanges. Also, phonological errors almost exclusively affect open-class words (Dell, 1990; Garrett, 1975; Stemberger, 1984).

The dissociation between open- and closed-class words is also a well-established observation in aphasia research. The sentences produced by so-called Wernicke's fluent aphasics tend to contain appropriate closed-class words but many errors on open-class words. By contrast, in the classic

[1] Inflectional elements (i.e., *bound grammatical morphemes*) and closed-class words (i.e., *free-standing grammatical morphemes*) are grouped together because their sensitivity to speech errors presents similar regularities. This is especially true for normal speakers (Garrett, 1975), and it tends to be the case for aphasic speakers. Note, however, that the detailed pattern of performance with free-standing and bound morphemes can vary greatly from one patient to another (Miceli, Silveri, Romani, & Caramazza, 1989).

syndrome of Broca's aphasia, closed-class words tend to be omitted (or substituted) while the production of open-class words is relatively well preserved (e.g., Andreewsky & Seron, 1975; Friederici, 1982; Friederici & Schoenle, 1980; Gardner & Zurif, 1975; Gordon & Caramazza, 1983; Miceli, Mazzucchi, Menn, & Goodglass, 1983).

The impairment of closed-class word production is not necessarily an isolated deficit. Patients who omit closed-class words often have difficulties in other aspects of language production (e.g., in the process of sentence construction), and sometimes also in language comprehension. Berndt (2001) notes in her review that it is generally the case that the "omission of grammatical morphemes occurs in the context of disruption of other aspects of sentence construction" (p. 386). Accordingly, closed-class retrieval has very often been studied as a part of the process of sentence production. This choice is also motivated by the primary role of closed-class items in conveying sentential structure.

Andreewsky and Seron (1975) describe the reading performance of a patient who could read nouns and verbs in isolation, but who could not read various types of closed-class words such as auxiliary verbs, conjunctions, etc. When this patient was asked to read sentences containing ambiguous words (e.g., *car* meaning "bus" or "because"), he was able to read the noun but not the conjunction version of the homograph. Miceli et al. (1983) describe a patient (Case 2) who produced relatively long sentences—median length 10.1 words—in which most errors occurred on closed-class words. His language comprehension was normal. It can be noted that this performance lasted only a very short time post-onset. Mr Clermont (Nespoulous, Dordain, Perron, Bub, Caplan, Mehler, & Lecours, 1988) is a patient whose language production was also described as "agrammatic". His output was characterised by the omission and erroneous production of closed-class words during sentence production in a variety of tasks (spontaneous production, repetition, sentence reading, etc.), but not during single word production. The performance was similar in oral and written production. Interestingly, the patient performed very well in an anagram task, where he was asked to order a list of words—from the open and the closed class—in order to construct an appropriate sentence. The authors suggested an interpretation of Mr Clermont's deficit in terms of reduced temporal or mnestic processing capacities (Nespoulous et al., 1988, pp. 292–293). Patient ML, described by Caramazza and Hillis (1989), is somewhat similar to Mr Clermont. ML showed major difficulties producing complete sentences in speech or in writing, primarily because of errors involving closed-class words. As was true for the two previous cases, this patient's language comprehension was completely normal. The authors attribute this pattern of performance to a deficit affecting the stage of sentence encoding where the surface structure is specified, a stage that comprises closed-class word retrieval. This interpretation—as well as that given for the previous patterns of performance—may seem to be a very general one. In fact, part of the authors' discussion is devoted to the difficulty of specifying in precise computational terms the nature of this type of deficit. What is clear, though, is that brain injury can have a differential impact on the ability to produce words from the open and the closed-class.

The relationship between oral and written production

A critical aspect of the case we report below is the contrast shown by the patient's performance in the *oral* and the *written* modalities: The former is preserved whereas the latter involves errors on closed-class words. Discussing the performance of this patient requires a description of the assumptions currently made concerning the process of word and sentence *written* production.

As we have seen in the previous sections, various production models postulate that the (open-class) lexicon comprises two lexical levels of representation (e.g., Garrett, 1988; Kempen & Huijbers, 1983; Levelt, Roelofs, & Meyer, 1999). In these models, a modality neutral lexical representation—the lemma—codes the grammatical properties of words. This representation mediates the access to the phonological lexical representation of the word—the phonological lexeme. Production models that include lemmas have most often been constructed to account for speech production. However, the assumptions they make can be extended to include an account of written production (see discussions in Alario, Schiller, Domoto-Reilly, & Caramazza, 2003; Berndt & Haendiges, 2000). In such an extended model the lemma is connected to two lexemes, one in the phonological lexicon and one in the orthographic lexicon.[2] A second type of language production model does not postulate two levels of lexical processing, but only one (Caramazza, 1997; Starreveld & La Heij, 1996). In this view, lexical access involves the selection of phonological or orthographic lexemes directly on the basis of information at the message level.

Within these different types of models, one crucial specification is the relationship between the retrieval of phonological information and the retrieval of orthographic information. Irrespective of details concerning the implementation of the process of lexical access, it is generally admitted that the retrieval of orthographic information can happen independently of the availability of phonology. The main evidence to support this view is the existence of patients who present significantly impaired oral production (not due to peripheral processes such as articulatory execution) and relatively preserved written production (e.g., Caramazza & Hillis, 1990; Lhermitte & Derouesné, 1974; Miceli, Benvegnù, Capasso, & Caramazza, 1997; Rapp, Benzig, & Caramazza, 1997; Semenza, Cipolotti, & Denes, 1992). An important consequence of this "orthographic autonomy" is that orthographic representations are generally viewed as structured linguistic entities that are not simply generated via the transcoding of previously retrieved phonological sequences.

Consider now possible extensions of sentence production models to account for written production. The functional level of processing, where lexical items are attributed syntactic and/or thematic roles, is most probably common to oral and written production. These operations are generally thought of as modality independent.

The adaptation of the positional level of processing in a model of written production will take into account two aspects of this level of processing. First, the sentence frames that are retrieved/constructed at this level are presumably amodal representations of the surface phrase geometry.[3] This hypothesis implies that the same frames are retrieved during oral and written production. Second, the process of word form insertion must differ between the two modalities. During oral production, the phonological lexemes of open-class words are inserted in the frame slots, and the form of closed-class words is set by a separate process (as proposed by Garrett). Similarly, during written production, the orthographic (rather than phonological) lexemes of open-class words will be inserted, and the orthographic form of closed-class words will be specified by a separate process. This simple proposal for extending models of sentence production to the written modality implements the orthographic autonomy hypothesis, originally proposed for single-word retrieval. The retrieval and insertion of orthographic information in the sentence frames does not necessarily require the previous retrieval of the corresponding phonological representations.

Modality-specific dissociations of open- and closed-class words

Besides the previously mentioned cases of superior performance in writing than in speaking, certain types of modality-specific dissociations provide support for the independence of phonological and orthographic retrieval. The cases that are of interest

[2] Alternatively, it could be postulated that the distinction between modalities of output is implemented earlier and that each word is represented by two lemmas. In this second view, one lemma gives access to the phonological lexeme and the other to the orthographic lexeme. Although logically possible, this hypothesis seems to run counter to the logic of postulating a lemma.

[3] This is under the assumption that the form of closed-class words is not an integral part of the positional level sentence frames; see previous discussion.

to us are those where modality-specific deficits selectively affect open- or closed-class words. Rapp and Caramazza (1997) described a patient (PBS) who presented complementary dissociations between open- and closed-class words in his oral and written output. In oral sentence production, this patient made many errors on open-class words. By contrast, when he was asked to produce sentences in writing, he made most of his errors on closed-class words. Somewhat similar patterns have previously been mentioned in the literature (Assal, Buttet, & Jolivet, 1981; Lecours & Rouillon, 1976; Lhermitte & Derouesné, 1974; Patterson & Shewell, 1987). Rapp and Caramazza's study provides the first extensive analysis of this pattern that is interpreted in the theoretical framework of models of oral and written sentence production. The authors argue that PBS's spoken and written deficits can be located at a level of processing that is downstream from syntactic processes. In this interpretation, sentence positional frames would be preserved and the deficit would affect the retrieval of phonological and orthographic lexical representations that are marked for their grammatical class. Among other things, this interpretation suggests that the retrieval of the orthographic form of closed-class words is independent from the retrieval of sentence frames. A related case is reported in the previously cited study by Miceli et al. (1983, Case 1). This patient shows a typical "agrammatic" output with short and fragmentary sentences, as well as numerous omissions and substitutions of closed-class words. Importantly for us, his written production was entirely normal, devoid both of literal paragraphias and of grammatical disturbances. Particularly, his written production of closed-class words was described as normal. The fact that written sentences were produced correctly necessarily means that the retrieval of sentence frames is preserved in this patient.

In the present study we report the performance of a patient (CB), which presents a modality-specific dissociation that is in some sense opposite to that of Case 1 described by Miceli et al. (1983). As we describe below, patient CB made many errors on closed-class words during sentence writing. By contrast, his written production of single words and his oral production of words and sentences were by and large normal. After describing the patient's performance, we will use the restricted character of his impairment to constrain models of sentence construction and closed-class word retrieval.

CASE STUDY

In this section we report an empirical investigation of the patient's performance, with a special emphasis on tasks involving language production. We begin with a short description of the patient's medical record, then report the patient's performance in single word processing, including oral and written production. Finally, the patient's sentence processing abilities are described with, again, special attention paid to oral and written production performance.

Medical record

CB is a 65-year-old, right-handed male who holds a PhD degree. He previously worked as a professor in a major university. Four years prior to this study (1998) he suffered an ischaemic stroke in the territory of the middle cerebral artery resulting in aphasia. A CT scan revealed a large fronto-insular lesion in the left hemisphere (see Figure 1).

A clinical neuropsychological evaluation was conducted prior to the study reported here. CB scored within normal limits (28/30) in a French version of the Mini Mental Status Examination (MMSE). This test provides a general evaluation of performance in orientation, memory, mental calculation, etc. In a digit span task, the patient was able to recall a maximum of 5 digits forward and 2 digits backward. In the Corsi block test—an evaluation of the visuospatial span—he reproduced sequences of up to 7 items forward and 5 items backward.

The results of the language screener showed that CB's language comprehension was very good. The patient was administered a subset of the tasks in French of the Boston Diagnostic Aphasia Examination (BDAE; Goodglass, Kaplan, & Barresi, 2001). He scored 15/15 in the order task, and 8/12

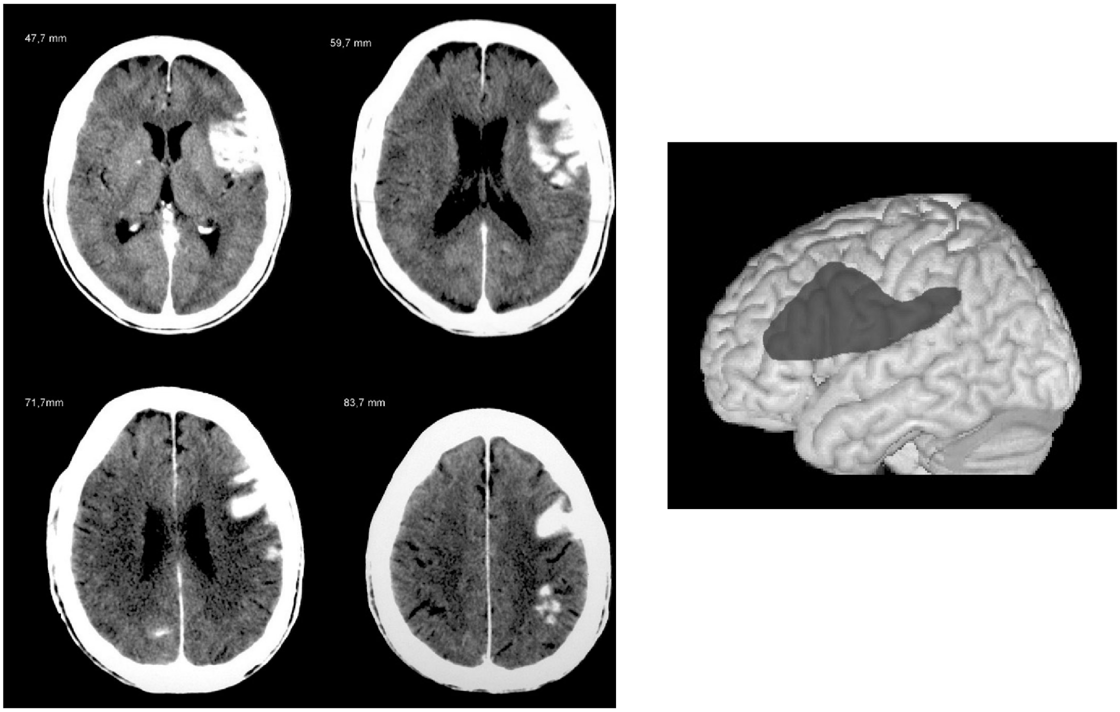

Figure 1. *CT-scans (left) and an approximate reconstruction of CB's lesion projected onto a normalized brain (right). The lesion affected Broca's region, the inferior rolandic cortex, and the insula.*

in the tests of reasoning. His comprehension of written sentences was also very good (9/10 correct). Oral production of single items was also very good: the oral picture-naming task was flawless (96% correct responses), and word and nonword repetition were 8/10 and 4/5 correct, respectively. His errors were all phonological paraphasias. Reading was relatively preserved, again with phonological errors (words: 7/10 correct; nonwords: 3/5 correct). In the semantic fluency task, the patient produced 18 animal names in 1 minute, whereas in the phonological fluency task—where he was asked to produce words that start with the letter "M"—he only gave 3 responses in 1 minute.

Spontaneous oral production was described as informative, with appropriate use of the lexicon and syntax. Some articulation difficulties were noted: speech was slow and over-syllabified. In written expression, graphemes were well formed but slightly altered by a discrete hand tremor. Important difficulties were noted with grammatical words. As an example of spontaneous language production, CB was asked to describe the well-known "Cookie Theft" picture from the BDAE, orally or in writing, on different days. The transcript of his productions can be found in Table 1 (see also Appendix A). Oral production was largely correct, with syntactically and semantically appropriate sentences. CB produced 20 open-class words and 20 closed-class words, among which there was one morphological error ("*il atteignent*" for *il atteint*, "he reaches"). The written description of the picture contained a larger number of errors, notably selection errors on closed-class words. CB produced 20 open-class words, 2 of which involved a morphological error (e.g., *placard* → "placards"). He produced 17 closed-class words, 4 of which were inappropriately used. Finally, he omitted 1 mandatory preposition (open-class: 95% correct; closed-class: 72% correct), $\chi^2(1) = 2.18$, $p = .14$. In

Table 1. *Transcript of CB's description of the cookie theft picture in the oral and the written modality, with an approximate English translation (see also Appendix A)*

Oral production	*Written production*
Les enfants veulent attraper des gâteaux dans le....dans le placard. Il prend un tabouret, il att**eignent**$_{morph}$ les gâteaux et le petit garçon tombe. Pen**s**ant$_{phon}$ ce temps là, la la ma-maman rêve en essuyant une assiette et le… l'eau fuit sur le parquet	Une fille dit au**x**$_{morph}$ gar**c**on$_{orth}$ [**d'**$_{miss}$] aller chercher les g**a**teaux$_{orth}$ qu'**ils**$_{inapp}$ sont **au**$_{inapp}$ placard**s**$_{morph}$. Le garçon monte sur le tabouret. Le tabouret s'effondre.La maman entend le bruit.La maman laisse le robinet **qu'**$_{inapp}$ **il**$_{inapp}$ déborde
The kids want to get the cookies in the … in the cupboard. He takes a stool, he **reach**$_{morph}$ the cookies and the little boy falls. Mea**m**while$_{phon}$ the the mo-mother is day dreaming while wiping a plate and the … the water leaks on the floor	A girl tells to **the**$_{morph}$ **boy**$_{orth}$ [**to**$_{miss}$] go get the **cookies**$_{orth}$ that **they**$_{inapp}$ are **at**$_{inapp}$ the cupboard**s**$_{morph}$. The boy climbs on the stool. The stool collapses. The mother hears the noise. The mother lets the faucet **that** $_{inapp}$ **it** $_{inapp}$ overflows

Errors are indicated by boldface underlined characters.
Errors: morph = morphological; phon = phonological; orth = orthographic; miss = missing item; inapp = inappropriately used item.

spite of these errors, the syntactic structure of the sentences produced by CB was largely correct.[4]

Experimental investigation: Single word processing

In the first experimental investigation, CB's language abilities were assessed on various tasks (picture naming, word reading and writing, nonword processing) involving the production of single items (words and nonwords), or very simple sequences such as determiner + noun noun phrases. All tasks were administered in an oral and in a written version.

Picture naming

CB was asked to name orally a set of 28 pictures of common objects from the Snodgrass and Vanderwart (1980) battery. He was instructed to use simple noun phrases to describe the pictures (definite article + noun; e.g., *la table*, "the table"). CB's performance was very good overall, with correct responses on 23 trials (82%), and only minor errors. These errors included the omission of a determiner on one trial, the use of an indefinite article instead of the required definite article on another trial, two phonological errors on nouns (*cocotier* → /rtchotcotier/; *cactus* → /cash tus/), and one disfluency (/la/ … /pom/, "the… apple"). In the written version of the task, the patient was given 40 pictures from the same source and he was asked to write down their names with the appropriate definite determiner. CB provided the correct response in 34 trials (85%). Again, his errors were for the most part minor deviations. He named the picture of a leaf as "*la feuille de vigne*" ("the vine leaf"), he made an agreement error on a determiner that he immediately self-corrected (*cerise* → "*le... la cerise*", the$_{masc}$…the$_{fem}$ cherry$_{fem}$), he used an indefinite determiner in one trial, and he produced no response in two trials.

Reading and writing open-class words

CB was asked to read aloud and to write down a list of 54 words. The words were all common nouns that were either mono-, bi-, or tri-syllabic. In reading CB made very few errors (3 errors, 94% correct): he read the word *aiguille* ("needle") with a hesitation (/E/…/Eguille/), he added a determiner in front of the word *cigarette* (read as "*la cigarette*"), and he made a phonological error on *parapluie* (/paraplɥi/ read as "/parəplɥi/"). His performance

[4] Some of the expressions used by the patient are somewhat awkward from a semantic point of view, although they cannot be considered as incorrect (e.g., "the stool collapses").

in writing to dictation the same words was also very good. Forty-eight of the 54 words were written correctly (89% correct). His errors never involved more than two letters per word (e.g., *écureuil*, "squirrel," → "*écureil*"). Overall, then, CB showed a similar performance in the two transcoding tasks, $\chi^2(1) < 1$ (see Table 2), producing only a handful of minor errors. Most often these errors consisted of minor surface deviations from an otherwise correctly selected target item.

Reading and writing open-class vs. closed-class words

CB was asked to write various word lists to dictation. The first list comprised 15 open- and 15 closed-class words, matched for frequency and length (in letters, phonemes, and syllables). This list is a subset of the list used by Segui, Frauenfelder, Lainé, and Mehler (1987). CB made 4 errors: one minor orthographic error on an open-class word (*hôtel* → "*hotel*"), and 3 errors on closed-class words (2 orthographic phonologically-plausible errors *voilà* → "*voila*"; *sitôt* → "*citeau*"; and one lexical substitution: *mien* → "*mes*"). The main difference in performance between open- and closed-class words in this list was that for the latter there was a lexical substitution. The second list included 35 closed-class words and 35 open-class words. CB made 2 errors: one on a closed-class word (*leur*, "their" → "*heure*," "hour") and one on an open-class word (*croc*, "fang" → "*grog*," "grog"). Also, he wrote 7 unexpected homophones—e.g., *ou*, "or" → "*houx*," "holly"; but these responses were not counted as errors. The performance in writing open- and closed-class words to dictation is summarised on Table 2. In contrast with the performance observed in the clinical test (Cookie Theft picture) CB has no problem writing words in isolation. The few errors he made are as likely to occur on any of the two categories of stimuli, $\chi^2(1) < 1$ (see Table 2).

On a different day, CB was asked to read out loud the 100 words of the writing to dictation lists. He made 4 errors: 1 no response (*drap*, "bed-sheet"), one phonological error (on *pitre*, "clown"), and two lexical errors (*paix*, "peace" → "*pelle*," "shovel"; *chaque*, "each" → "*chaqu'un*", "each one", self-corrected).

Nonword processing

On different days, CB was asked to read, to write to dictation, or to repeat a list of 35 nonwords. CB's performance in reading and writing was low. He performed better on the repetition task: effect of task, $\chi^2(2) = 16.0$, $p < .01$ (see Table 2).

In repetition, the errors were always mild deviations from the intended target. Generally, only one phoneme differed between the intended target and

Table 2. *CB's performance with isolated words and nonwords*

Stimuli	*Task*	*N*	*Errors*		*% err*	
Common nouns	Reading	54	3		6%	
	Writing to dictation	54	6		11%	
Open-class words	Reading	50	3		6%	
	Writing to dictation	50	2		4%	
Closed-class words	Reading	50	1		2%	
	Writing to dictation	50	4		8%	
		N	*Lexical*	*Other*	*% err*	*% corr seg*
Nonwords	Reading	35	6	17	66%	65%
	Writing to dictation	35	4	24	80%	51%
	Repetition	35	2	10	34%	84%

Lexical = lexicalisations; % err = percentage of errors; % corr seg = average percentage of correct segments in the erroneous responses (see text for details).

the response given (e.g., *gurette* → "/dyrɛt/," where /gyrɛt/ is expected). These errors could be due to a mild general phonological deficit. As we have seen, the patient also made a few similar phonological errors in picture naming or word reading. The fact that CB's performance in nonword repetition is good suggests that his perceptual (acoustic to phoneme) and production (phoneme to acoustical) conversion processes are largely preserved.

CB's erroneous responses in the two nonword transcoding tasks (reading and writing to dictation) often included a few correct letter or phoneme sequences (e.g., in reading: *nurvade* → /nivyrɑ̃/, where /nyrvad/ was expected; in writing to dictation: /plicaʒ/ → "pilcar"). To provide an evaluation of the degree of availability of partial sublexical conversion abilities we counted the number of correct segments (phonemes or letters) that could be found in the erroneous responses. We compared the response given with the most probable pronunciation or writing of the target nonword. A segment was scored as correct provided it was produced in the correct syllable of the target nonword. With this approximate count, CB's oral responses contained 65% correct phonemes and his written responses contained 51% of correct letters (note that only erroneous responses are included in these figures). In sum, CB's sublexical conversion procedures were impaired although not totally unavailable. Furthermore, grapheme-to-phoneme conversion seems somewhat more efficient than phoneme-to-grapheme conversion.

Summary of the investigation of single-word processing

The assessment of CB's single-word processing has established the following facts. First, the patient's production of single words and very simple utterances such as noun phrases is largely intact, irrespective of the modality of input—picture or word—and the modality of output—oral or written. In particular, the patient is just as good at processing open- and closed-class words in isolation. By contrast, the ability to process nonwords in the written modality is only very partially preserved. When reading nonwords or writing them to dictation, CB produces many errors. In all cases these errors retain a clear orthographic or phonological resemblance with the expected response.

Experimental investigation: Sentence processing

The investigation of CB's performance in sentence processing was based on the following experimental tasks: sentence comprehension, spontaneous language production, sentence construction from a single word, sentence transcoding (reading, repeating, and writing to dictation), and writing series of unrelated words. Most of these tasks involved a direct comparison of the oral and written modalities.

Sentence comprehension

Although we were primarily interested in the investigation of sentence *production*, some of the experimental tasks that we used involved the comprehension of sentences. Therefore, we assessed CB's sentence comprehension in a classic dual-choice task. The patient hears a sentence and he is asked to choose which of two pictures better depicts the situation described by the sentence. We used a French version of the CNLab Sentence Comprehension battery. This test involves reversible and irreversible sentences in their active or passive form, sentences that vary on the grammatical number of the subject or the grammatical number of the direct object, and sentences that require the comprehension of prepositions. CB's performance was very good in all conditions (see Table 3). The apparent trend for reversible sentences to produce more

Table 3. *CB's performance in the three components of the sentence comprehension task*

Type of sentence	*N*	*N correct*
Reversible—active	17	15 (88%)
Reversible—passive	17	15 (88%)
Irreversible—active	17	17 (100%)
Irreversible—passive	17	17 (100%)
Subject number	16	16 (100%)
Object number	16	15 (94%)
Preposition comprehension	24	24 (100%)

errors than irreversible sentences was not significant, χ^2 (3) = 4.25, p = .24. This means that the patient's comprehension of the different aspects of a simple sentence (lexical items, role assignment, agreement, prepositions) is intact.

Spontaneous sentence production

In order to get a large sample of spontaneous language production, CB was asked to describe various types of daily activities or short stories ("what did you do this morning?," "story of illness," "plot of a movie or theatre play," "Cinderella's tale," "what happens on election day?," "describe how to make an omelet"). The oral and the written description of each of the topics that we used were produced on different days.

In the oral modality, CB produced a total of 520 words: 216 open-class words and 304 closed-class words (i.e., 59% closed-class). The average length of his sentences was 9.5 words (range 3–21). CB produced speech at a relatively slow rate, but the sentences he produced were semantically appropriate and wellformed; he made very few errors overall. Minor phonological deviations on otherwise recognisable words were considered as sublexical errors (N = 17, 8%; all on open-class words). These sublexical errors are not thought to occur during the process of word selection, but rather during the subsequent stages of phonological encoding, phonetic encoding, or articulatory execution (e.g., Garrett, 1975). Given our interest in the earlier stages of language production, sublexical errors were not included in our counts. Besides sublexical errors, the oral production also involved a few lexical errors (omissions or substitutions; see Table 4). The occurrence of these errors was as likely on the two word classes (3% vs. 4%), $\chi^2(1) < 1$.

In the written modality, CB produced 47 sentences comprising a total of 149 open-class words and 154 closed-class words (i.e., 51% closed-class). The average length of his sentences was 7.3 words (range 2–17). All but two of his sentences were semantically coherent and conveyed an appropriate meaning—for the two other sentences it was impossible to determine what was meant. Contrary to what was observed in speech production, CB's written production comprised many errors. He produced sublexical errors (i.e., minor orthographic deviations) on 4 of the open-class items (3%). For the reasons we have noted these errors will be disregarded in our counts. Of primary interest for our research is the fact that CB made many lexical errors, which included: word substitutions, word insertions, word omissions, and one shift. These errors were far more common on closed-class than on open-class items (open-class: 6%; closed-class: 36%), $\chi^2(1) = 32.1$, $p < .001$. Finally, there were 9 morphological errors, that is, errors on the bound morphemes—generally suffixes—of open-class words (e.g., producing "*époussir*" for *épous-er*, "to marry"). It is possible that the occurrence of morphological errors is related to the occurrence of lexical errors on closed-class items (i.e., free-standing grammatical morphemes). However, the number of morphological errors in our corpus was very small overall. It does not let us draw any strong conclusions about bound grammatical morphemes or about their relationship to closed-class words (see Miceli et al., 1989, for a discussion of this issue). Therefore, we will focus our analysis and

Table 4. *Error distribution for open- and closed-class words in the spontaneous language production task for the two modalities of output*

		Oral				*Written*			
Task	*Word class*	*Prod*	*Om*	*Other err*	*%*	*Prod*	*Om*	*Other err*	*%*
Spontaneous language production	Open	216	1	5	3%	149	3	6	6%
	Closed	304	4	9	4%	154	23	40	36%

This table does not include sublexical or morphological errors (see text for details).

Prod = produced; Om. = omissions; Other err. = substitutions, insertions, shifts.

The percentages of errors are the number of errors and missing words relative to the total number of words produced plus the number of words omitted (missing).

discussion on the occurrence of errors on words of the closed class (i.e., free-standing grammatical morphemes).

Table 4 presents a summary of the spontaneous production data after the exclusion of the sublexical or morphological errors. The basic observation is that CB has more problems with the production of closed-class words than with the production of open-class words, a dissociation that is *only* observed in *written production*. This result is supported by a significant interaction between modality of output and type of word on the percentage of errors, $\chi^2(3) = 107$, $p < .01$. A more detailed analysis of the types of errors produced by CB in writing will be given after the results of the sentence construction task are presented.

Table 5 presents a quantitative analysis of CB's spontaneous oral and written production (Rochon, Saffran, Berndt, & Schwartz, 2000; Saffran, Berndt, & Schwartz, 1989). The data concerning verb and auxiliary production were not tabulated due to the large differences in verb structure between English, the language the analysis was originally devised for, and French, the language used by our patient. As can be seen in the table, the vast majority of the sentences produced by the patient were syntactically well formed in speech. In a sense this was also the case in writing. Of course, written sentences included a large number of errors on closed-class words (e.g., substitutions or omissions). Therefore, strictly speaking they cannot be considered as syntactically correct. However, in many cases the patient's intention could be easily recognised. That is to say, if lexical errors on closed-class words were to be corrected, the syntactic structure of the resulting sentences would in most cases be appropriate. Whenever this was the case, the sentence was scored as *well formed*. An illustration by means of some examples of the patient's production can be found in Appendix A. Although the patient did not have a greatly elaborated syntax—as indicated by the relatively low embedding and elaboration indexes—his production was clearly distinct from the "telegraphic" style sometimes observed in agrammatic patients (Saffran et al., 1989). These observations argue in favour of a relative preservation of the process of sentence construction in this patient.

Sentence construction from a single word

In each trial of this task CB was given a single word and he was asked to say or to write a sentence using that word. We used 39 words as cues, mostly common and proper nouns. The oral and the written versions were administered on different days. In the oral version of the task, CB produced 149 open-class words and 115 closed-class words. His sentences were on average 7.2 words long (range 4-12). Overall, he made very few errors: 4 lexical errors and 5 errors of other types. Of the 4 lexical errors, 3 were on open-class words: He clearly omitted the word *restaurant* in an utterance,

Table 5. *Quantitative production analysis of CB's spontaneous oral and written production (Saffran et al., 1989)*

Type of measure	*Index*	*Oral*	*Written*
Corpus measures	Number of utterances	55	47
	Number of narrative words	520	303
	Mean sentence length	9.45	7.30
Structural measures	Proportion of sentences well formed	0.96	0.89
	Proportion of words in sentences	1.00	0.89
	Structural elaboration of sentences (subject NP + VP)	2.32	1.30
	Embedding index	0.33	0.24
Morphological measures	Proportion of closed-class words	0.59	0.51
	Noun / pronoun ratio	1.15	2.36
	Determiner / noun ratio	1.00	0.83
	Noun / verb ratio	1.05	1.57

Table 6. *Error distribution for open- and closed-class words in the sentence construction task for the two modalities of output*

		Oral				*Written*			
Task	*Word class*	*Prod*	*Om*	*Other*	*%*	*Prod*	*Om*	*Other*	*%*
Sentence construction task	Open	149	1	2	2%	168	2	4	4%
	Closed	115	0	1	1%	137	7	20	19%

This table does not include sublexical or morphological errors (see text for details).
Prod = produced; Om = omissions; Other = substitutions, insertions, shifts.
The percentages of errors are the number of errors and missing words relative to the total number of words produced plus the number of words omitted (missing).

and he substituted the word *ville* ("city") for *capitale* ("capital") and the word *soigner* ("to take care of") for *se laver* ("to clean oneself"). One of the lexical errors affected a closed-class word: The plural indefinite article *des* was substituted for its singular version *un*. The errors that were not lexical were as follows. There were 3 phonological errors on open-class words and 1 on a closed-class word (e.g., *croire* → "/trwar/"; *du* → "/di/"). There was one morphological error (*vient*, "he comes" → "*viennent*," "they come"). In sum, CB's oral responses in this task were correct, with only a few minor deviations. The performance on open- and closed-class words did not differ (open-class 3% vs. closed-class 1%), $\chi^2(1) < 1$.

In the written version of the task CB produced sentences that were on average 7.9 words long (range 4–20). He produced 168 open-class words and 137 closed-class words. On open-class words, CB made 6 lexical errors (4 substitutions and 2 omissions), 5 orthographic errors (3% of the open-class words), and 7 morphological errors (4% of the open-class errors; morphological errors are errors on bound grammatical morphemes used in open-class-words). On closed-class words, performance was much worse. There were many lexical errors: 20 errors (substitutions or insertions) and 7 omissions, resulting in a total of 19% of errors on closed-class. There were no orthographic errors on closed-class items. Performance on closed-class words was significantly worse than on open-class words in the written modality (open-class = 4% vs. closed-class = 19%), $\chi^2(1) = 17.6$, $p < .01$ (see Table 6).[5]

Thus, as was the case in the spontaneous production task, the basic finding in this task is that CB has more problems with the production of closed-class words than with the production of open-class words for writing, $\chi^2(3) = 34.5$, $p < .01$.

Further analysis of the written production corpus

Since CB made most of his errors while writing, in this section we present a detailed analysis of the errors he produced in this modality of output. The spontaneous production task and the sentence construction task lead to similar patterns of performance; therefore, to increase the number of observations, the results in the two tasks were analysed together. We classified the errors made in this modality of output by grammatical categories within the open and the closed class (see Table 7).

Table 7 shows that verbs are the words that are responsible for most of the errors within the open class (after excluding the under-represented category of adverbs), $\chi^2(2) = 18.7$, $p < .01$. Verbs still induce fewer errors than any category of closed-class words.

CB made 9 word substitutions when writing open-class words. One of the substitutions

[5] The dissociation between open- and closed-class words in this task is very similar to that observed in spontaneous production. It can be noted that the sentence construction task led to fewer errors than spontaneous production. We do not have a principled explanation for this fact. This relative reduction in error rates might be related to the observation that the messages expressed in the construction task were simpler than in spontaneous production.

Table 7. *Error distribution for each grammatical category in CB's spontaneous written production and sentence construction*

	N	*Substitutions*	*Insertions*	*Other*	*Omissions*	*% error*
Open-class						
Nouns	181	0	0	1	0	1
Verbs	109	7	0	1	5	11
Adjectives	25	1	0	0	0	4
Adverbs	2	0	0	0	0	0
Total	317	8	0	2	5	5
Closed-class						
Determiners	123	20	8	1	11	30
Pronouns	51	3	1	2	5	20
Prepositions	70	10	7	1	11	36
Auxiliary verbs	23	5	0	0	2	28
Adverbs	20	1	0	1	1	14
Conjunctions	4	0	0	0	0	0
Total	291	39	16	5	30	28

concerned an adjective: the patient produced "*plus*" ("more"), where "*petit*" ("small") was expected. All other substitutions concerned verbs, always replaced by verbs. For verb substitutions, the produced and expected verb shared a semantic relationship in one case (at least in the context where it was produced: "*organise*", "organises" → *permet*, "allows"); two substitutions had a phonological relationship with the expected word (e.g., *recueille*, "he collects" → *retourne*, "returns"). All other substitutions bear no relationship with the expected word. What this short analysis shows is that there is no systematic origin of these errors in CB's written production.

The probability of error is homogeneous across grammatical categories within the closed class (after exclusion of the under-represented category of conjunctions), $\chi^2(4) = 6.26$, $p = .18$. An important aspect of CB's errors is the fact that among the 39 word substitutions he made on closed-class words, 29 (i.e., 74 %) preserved grammatical category.[6] This observation can be related to a point made earlier. The sentences produced by CB were very often syntactically well formed. In most cases, when a sentence involved a word error the structure of the intended utterance was clearly recognisable despite missing or substituted items. This could suggest that the difficulties encountered by CB are related to the retrieval of the orthography of certain words, especially of closed-class words, rather than to the construction of sentence structure.

A final analysis of CB's written production corpus looked at the position of the errors he produced. In this analysis, we evaluate whether the occurrence of open- and closed-class errors is dependent on the position of the words in the sentences. The sentences produced by CB in the spontaneous production task and in the sentence construction task differed greatly in length. In order to make word positions comparable across sentences, a normalised word position was computed for each word of the corpus. Each word was first given its ordinal position in the sentence where it appeared. A proportionality rule was then applied to provide a relative-position number that allowed classifying words into four bins: words belonging to the first, second, third, and fourth quarter of the sentence.

[6] A more detailed analysis of the relationship between expected and actually produced words in closed-class word substitutions is reported below. This analysis integrates data from spontaneous production, sentence construction, and writing sentences to dictation.

Table 8. *Relative position of closed- and open-class words in the sentences, along with the number of errors produced*

Task	*Relative position*	*Open-class Prod*	*Open-class Err*	*Open-class % err*	*Closed-class Prod*	*Closed-class Err*	*Closed-class % err*
Spontaneous production and sentence construction	1st quarter	45	0	0	85	15	18
	2nd quarter	91	5	5	76	20	26
	3rd quarter	72	6	8	82	23	28
	4th quarter	114	4	4	78	31	40
Writing to dictation	1st quarter	94	9	10	132	21	16
	2nd quarter	119	11	9	158	35	22
	3rd quarter	100	13	13	150	42	28
	4th quarter	150	13	9	160	56	35

The error count includes omissions.

The proportion of errors on closed-class words was significantly affected by sentence position, $\chi^2(3) = 10.4$, $p = .02$ (see Table 8). Furthermore, there was a clear correlation between the occurrence of errors on closed-class words and their position in the sentence. The relation between proportion of errors and relative position in the sentence was linear ($r^2 = .93$, see Figure 2). As we have already seen, open-class words induced very few errors; the proportion of errors in each sentence position did not differ significantly from each other, $\chi^2(3) = 4.91$, $p = .18$. Fitting the relationship between the proportion of errors on open-class words and relative position in a linear regression did not capture much of the variance in the data ($r^2 = .24$; see Figure 2). To sum up, the probability of error on closed-class words increases linearly with relative position; the probability of error on open-class words does not follow that pattern. The implications of this finding will be addressed in the General Discussion.

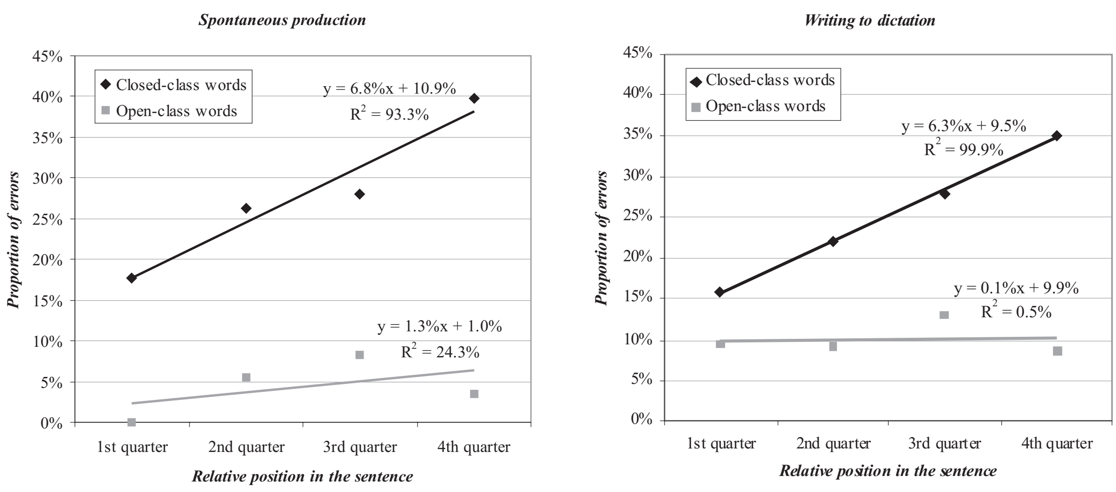

Figure 2. *Proportion of errors on closed- and open-class words plotted against their relative position in the sentence. Closed-class words show a linear increase trend, which is not apparent for open-class words. Left: data from the spontaneous production task (spontaneous production and sentence construction from a word); right: data from the writing to dictation task.*

Writing sentences to dictation

The assessment of single-word processing has shown that the patient is able to write to dictation open- and closed-class words in isolation almost flawlessly and at similar levels of performance. Based on this observation, it could be expected that CB would write sentences to dictation at a better level than that he achieved in the spontaneous production tasks. This expectation is based on the assumption that the patient can make use of the phonological information available when a sentence is dictated to him. For example, he could use recursively the phoneme-to-grapheme conversion procedures during sentence writing.

We created a set of 36 sentences that included an important number of closed-class words (e.g., ***Je ne*** *sais* ***pas ce que vous*** *voulez*, "I do not know what you want"; closed-class words are in bold in the French example). On average, the sentences in this set (Set 1) had 7.6 words (range: 4–12), 3.1 of which were open-class words (41%) and 4.5 closed-class words (59%). Besides the writing to dictation task, on different days CB was asked to read the same sentences and to repeat them orally. These two tasks provided a control of his ability to process and maintain in memory complex linguistic stimuli.

In the writing to dictation task, the pattern was *very similar* to the pattern reported in the spontaneous production task. CB produced significantly more lexical errors on closed-class words than on open-class words (see Table 9). As before, the data reported in the table do not include the sublexical and morphological errors. When writing these sentences to dictation, CB made 4 minor orthographic errors, all of them on open-class words. He also made 6 morphological errors on open-class words and 1 on an auxiliary verb (he used the wrong person: "avez", $\text{have}_{\text{2nd-Plural}} \rightarrow$ "avais", $\text{have}_{\text{2nd-Singular}}$). The difference in performance between open- and closed-class words was significant, $\chi^2(1) = 16.4$, $p < .01$.

Contrary to the writing to dictation tasks, reading and oral repetition lead to very few errors. These errors affected equally the category of open- and closed-class words (for repetition and reading), $\chi^2(1) < 1$.

In sum, CB had trouble writing the closed-class words of sentences he was able to read and to repeat almost flawlessly. In fact, the pattern of performance in writing sentences to dictation is similar to the pattern of performance in the spontaneous production tasks (i.e., many more errors on closed-class words than on open-class words during

Table 9. *Performance in the written and oral sentence production tasks by word category*

Sentence set	*Task*	*Word category*	*N*	*Miss*	*Err*	*% err*
Set 1	Writing to dictation	Open class	109	2	3	5
		Closed class	155	17	20	24
	Repetition	Open class	109	0	2	2
		Closed class	155	2	3	3
	Reading	Open class	109	0	3	3
		Closed class	155	1	5	4
Set 2	Writing to dictation	Open class	163	6	10	10
		Closed class	232	32	31	27
	Secondary recall	Open class	163	1	0	1
		Closed class	232	1	2	1
Set 3	Writing to dictation	Open class	190	22	4	14
		Closed class	214	24	31	26

N = number of items produced; Miss = missing words; Err = lexical errors; % err = proportion of errors among produced items.

writing) and not to the pattern of performance in single-word writing to dictation (where closed-class words did not lead to more errors than open-class words, and where there were very few errors overall).

Multimodal (written then spoken) sentence production

One possible interpretation of the contrast between oral and written sentence production found in the previous section could be given in terms of short-term memory. It could be argued that the errors occur more in writing than in speech because this modality of output demands longer processing times. The short-term representation in which the sentence to be processed is stored would be more subject to decay in the written than in the oral task. Of course, to be complete this explanation would have to specify why closed-class words are more sensitive to decay (and therefore lead to more errors) than open-class words.

Before specifying these details, we report an experiment where the validity of this general line of reasoning was tested. In this task, CB was asked to write down a sentence and, *after he had written it*, he was asked to repeat it from memory, without looking at what he had written. We reasoned that if decay of a short-term memory representation of the sentence to be written was responsible for the pattern observed in the previous task, then the oral recall of the sentence should be no better than the written production. In particular, it should contain a disproportionate number of errors on closed-class items.

We constructed a new set of 50 sentences (Set 2) that contained 41% open- and 59% closed-class words. These sentences were 8.0 words long on average. Two sentences were excluded from the analysis because CB said he did not understand them—later it appeared that he had misheard some of the words. Table 9 shows the pattern of results for the written production and the secondary oral recall of the sentences. Note that it only includes lexical errors (CB also made 1 orthographic errors and 12 morphological errors on open-class words, 7%). As was the case previously, we observe the dissociation between open- and closed-class words in the written production, $\chi^2(1) = 16.9, p < .01$. No systematic difference was observed between the two types of words in the immediate recall, which was basically flawless. Remember that the oral recall response was given *after* the production of the written response where errors had occurred. We can note as anecdotal evidence that after recalling the sentences, CB would sometimes go back to what he had written and would be incapable of correcting his errors, although he would sometimes point to them correctly (e.g., "something is wrong here").

The results of this experiment make it clear that the dissociation between open- and closed-class words observed when CB writes sentences to dictation cannot simply be attributed to a greater decay of the representation of the target sentence during writing.

Further analysis of the performance in writing to dictation

We conducted a series of analyses on the written corpus produced in the writing to dictation tasks, similar to the analysis we have reported earlier for the spontaneous production and sentence construction tasks. The data included in this analysis are those of the first writing to dictation task (Set 1), those of the multimodal task (Set 2), and those of a third and final set of 40 sentences CB was asked to write. The similarity of results for the three sentence sets allows us to group them together.

The overall difference in performance between open- and closed-class words in these three data sets was significant (open-class: 10% errors; closed-class: 26% errors), $\chi^2(1) = 19.5, p < .01$.[7] The data

[7] In the whole corpus there were 35 morphological errors, which represent 7.6% of the open-class words. Most of these errors were on verbs. As pointed out earlier, we will continue to highlight in our discussion the occurrence of errors on closed-class words rather than on bound grammatical morphemes.

Table 10. *Error distribution for each grammatical category in the task of writing sentences to dictation*

	N	*Substitutions*	*Insertions*	*Shifts*	*Omissions*	*% err*
Open-class						
Nouns	210	5	0	0	10	7
Verbs	194	4	2	0	17	12
Adjectives	50	1	0	0	5	12
Adverbs	8	0	0	0	3	38
Total	462	10	2	0	35	10
Closed-class						
Determiners	161	37	1	2	21	38
Prepositions	118	13	0	3	12	24
Conjunctions	38	1	0	0	0	3
Pronouns	172	13	2	1	26	24
Auxiliary verbs	36	2	0	0	5	19
Adverbs	73	5	0	0	9	19
Adjectives	3	2	0	0	0	67
Total	601	73	3	6	73	26

were classified according to the grammatical category of the words. Table 10 shows that the occurrence of errors is homogeneous across grammatical categories within the open class (after excluding the under-represented category of adverbs), $\chi^2(2) = 2.9$, $p = .23$. Therefore, contrary to what was observed in the previous analysis, the sentence writing to dictation task does not lead to more errors on verbs (compared to other open-class words). CB made 10 substitutions on open-class words (2% of that class). These substitutions preserved grammatical category in 60% of the cases. Some of them were semantically related to the target word (60%), but most of them bore a phonological relationship to it (80% of the substitutions). To summarise, a variety of sources seems to contribute to the occurrence of this type of error, with a preference for phonological confusions. Due to the limited number of errors available, no further attempt was made to discriminate among them.

There are some differences between the error rates for the different categories of the closed class (Table 10). Determiners produce the highest error rate (38%), whereas auxiliaries and adverbs produce the lowest error rates (19%, after exclusion of the under-represented category of closed-class interrogative adjectives). Still, in spite of these differences, after the exclusion of the under-represented categories, any type of closed-class word generates more errors than any type of open-class word.

As was done with the spontaneous production data, we analysed CB's production to evaluate whether the position of the words in the sentences had any relationship to the occurrence of errors. The same normalisation procedure used with the spontaneous production tasks was followed here. The results of this analysis are presented in Table 8. As can be seen, errors on closed-class words followed a monotonically increasing trend with respect to normalised position in the sentence. This trend is well accounted for by a linear relationship between proportion of errors and relative position, $\chi^2(3) = 15.3$, $p < .01$; $r^2 = .99$. By contrast, the proportion of errors on open-class words was pretty much constant with respect to the relative position in the sentence, $\chi2(3) = 1.40$, $p = .71$; (see Table 8 and Figure 2).

Analysis of closed-class word substitutions

Some information about the origin of CB's errors can be gathered by analysing the relationship between the expected target word and the word that he actually produced in substitution errors. A systematic pattern in these relationships could help in constraining possible loci of the deficit causing the errors.[8] In this analysis, we grouped the substitutions made by CB on closed-class words[9] in all sentence production tasks. Overall, CB made 112 substitutions, 39 in the spontaneous production tasks and 73 in the writing to dictation tasks. Of these 112 errors, 108 could be unambiguously analysed; they involved the production of only one word for another.

We first tried to determine whether substitutions were better explained by lexico-semantic factors or by surface factors. We compared class and category relationships between substituted words with orthographic/phonological similarity between them. In the 108 reported substitutions CB always produced a closed-class word, never an open-class word. Furthermore, he preserved grammatical category in 84 cases (78%). These two figures suggest that lexico-semantic factors, such as word class, are major determinants of the outcome of a substitution. Note, however, that in 56 substitutions (52%) the target and the produced word bore an orthographic/phonological relationship—they shared more than 50% of their segments. Still, surface similarity does not seem to be a major factor influencing the outcome of these errors. A more detailed analysis of the substitutions showed that the errors were mixed (i.e., shared grammatical class and surface form) in 41% of the cases, they shared only grammatical class in 37% of the cases, and only surface form in 11% of the cases. Also indicative is the analysis of the substitutions observed for the class of prepositions, a category of closed-class words whose members are not very similar to one another in French. CB made 24 substitutions on prepositions, producing another preposition in 18 cases (75%) and an orthographic/phonological neighbour in 7 cases (29%). The relationship between the expected and the produced word was *only* orthographic/phonological in 2 of these 7 cases. If surface similarity was driving word substitutions in a significant manner, one would expect a much more important production of words related by their surface properties, whether they are prepositions, members of another category in the other closed-class, or open-class words. Overall then, grammatical class is preserved in most of CB's substitutions, and this lexico-semantic similarity is to a certain extent independent of surface factors such as orthographic or phonological similarity. Note that in this analysis, we have treated the different features, from grammatical class to surface similarity, as if they could only have totally independent effects. This does not need to be so, however; in the General Discussion we address the issue of how various types of information can contribute together to closed-class word selection.

In a second analysis, we considered the particular category of determiners, which was the most frequent category in CB's substitution corpus—55 of the 108 substituted words were determiners (51%). The selection of determiners in French involves various types of informational features (e.g., determiner type, grammatical gender, etc.) We evaluated whether some of the features involved in determiner selection were better preserved than others in the errors. Four features were considered: grammatical class (possible values within the closed-class: determiner, pronoun, auxiliary verb, conjunction, preposition or adverb), type of determiner (possible values in CB's production: definite article, indefinite article, possessive adjective, demonstrative adjective), number (possible values: singular or plural), and grammatical gender (possible values: masculine or feminine). We used as baseline the probability of selecting the right feature if it were selected at random among the possible values we have just

[8] One well-known difficulty with this type of analysis is that the different types of similarities (grammatical, orthographic, etc.) might not be completely independent. For example, some pronouns or determiners are close orthographic neighbours in French. Research on so called *mixed errors*—open-class substitutions where there is a semantic and a phonological relationship between the expected and the produced word—has shown how difficult it can be to define different baselines that allow us to disentangle the different effects (e.g., Garrett, 1992). Therefore, the analysis reported in this section has to be taken cautiously, only as an indication of the possible underlying nature of CB's closed-class substitutions.

[9] The few substitutions observed on open-class words have been described in the previous sections.

described. Clearly, this definition of a baseline is not without problems, as it is possible that some unknown factor makes some features inherently more difficult to select or use than others. Still, these comparisons can provide cues as to the origin of the errors. The data presented in Table 11 show that grammatical class and number were largely preserved in CB's determiner substitutions. Type of determiner was processed significantly better than chance, although it produced a larger number of errors. Finally, performance with grammatical gender was at chance level. Besides the observation that grammatical class was preserved, these data suggest that the features that are more semantic in nature, i.e., the number of items referred to and the type of determination (possessive, definite, etc.) they are mentioned with, are better preserved than the more lexical feature of grammatical gender. In short, although it is hard to specify the locus of CB's deficit on the basis of these data alone, the observations suggest that all the features are not as affected by the deficit. The use of semantic features seems better preserved than the use of lexical features.

Writing open- and closed-class words in unrelated lists

CB's difficulties with closed-class words in the writing to dictation task are observed when he writes sentences but not when he writes isolated words. In this section we report his performance in a task for which the processing requirements lie somewhere between writing isolated words and writing complete sentences. The patient was asked to write down short lists of unrelated words that were either from the open or the closed class. In this experimental situation, the requirement is to write various words, but the stimulus provides no global structural properties as a sentence does. In our experiment, all the items within a given list were of the same class. The number of items per list increased from 1 to 5. In the whole task, CB was asked to write 49 words of each type—five lists of 1 word, five lists of 2 words, four lists of 3 words, three lists of 4 words, and two lists of 5 words. His performance was overall worse than in single-word production, a difference that can be readily attributed to the requirement of keeping several words in memory while performing the task. The errors that were observed were of two types: omissions (when the patient failed to produce a particular word that was in the intended list) and substitutions (when he produced a word that was not in the list he was asked to write, sometimes persevering from previous lists). Importantly, as can be seen from Table 12, there was no significant difference between the proportion of errors produced when transcribing open- or closed-class words, $\chi^2(1) < 1$.

Table 11. *Analysis of feature preservation for determiner substitutions in all sentence writing tasks*

		Produced		*Baseline*			
Type of feature	*Outcome*	*N*	*%*	*N*	*%*	$\chi^2(2)$	*p*
Grammatical class	Preserved	47	85	9	17	49.8	< .01
	Not preserved	8	15	46	83		
Type of determiner	Preserved	24	50	12	25	5.38	.02
	Not preserved	24	50	36	75		
Number	Preserved	40	83	24	50	10.5	< .01
	Not preserved	8	17	24	50		
Grammatical gender	Preserved	15	44	17	50	< 1	.81
	Not preserved	19	56	17	50		

The table presents the number of words (and corresponding percentages) for which each feature is selected correctly (preserved) or incorrectly (not preserved). The baseline values are estimates based on a random selection among all possible values for each feature. *N* values vary for each type of feature because the expected and the produced item do not always bear all the features—for example, plural determiners are not gender marked.

Table 12. *Performance in the written span task conducted with lists (up to 5 words long) of unrelated open- or closed-class words*

	N	*Corr*	*Sub*	*Om*	*% err*
Open-class	49	42	3	4	14
Closed-class	49	39	5	5	20

Corr = correct; Sub = substitutions; Om = omissions; % err = % errors.

Summary of the experimental investigation of multiword processing

The results we have presented show that the patient CB encounters very specific problems when he is asked to process multiword structured utterances. CB had no major difficulties in oral sentence comprehension or production. By contrast, he had a disproportionate difficulty producing words of the *closed class* in *written* sentence production. The dissociation between the closed- and the open-class words was observed in a variety of writing tasks such as spontaneous language production, sentence construction, and writing sentences to dictation. Control conditions show that the patient's difficulties in writing sentences to dictation cannot be attributed to input processes, since he read and repeated correctly the sentences he was asked to write. In particular, CB was able to repeat correctly the sentences he had trouble writing *after* he had written them. This suggests that his errors cannot simply be explained by his forgetting the sentence in the course of a writing trial. Two further analyses were conducted on CB's sentence production data. The first concerned the factors affecting the outcome of closed-class word substitutions. This analysis suggested two conclusions: Surface form (orthography or phonology) is not a major determiner of these errors and semantic features are relatively well preserved in these errors (at least for determiners). A second positional analysis clearly showed that errors on closed-class words followed a linear increasing trend: The proportion of errors increased with sentence position. Open-class words, which led to many fewer errors, did not show this tendency. Finally, the dissociation between open- and closed-class words was not observed when the patient was asked to write words in unrelated lists.

GENERAL DISCUSSION

The ability to produce sentences relies on processes of lexical retrieval and on processes of linguistic encoding—e.g., the construction of syntactic structures. Although there have been rather detailed theoretical proposals devoted to the organisation of these processes (see, for example, Bock & Levelt, 1994; Dell, 1986; Garrett, 1988), many aspects of sentence production remain to be understood. In this study we have reported the performance of a patient who, following brain damage, presents a specific deficit in his ability to write sentences. This patient makes a substantial number of errors when writing sentences but not when writing words in isolation; these errors primarily affect closed-class words. By contrast, his oral production is by and large normal. In the following sections we discuss the constraints that this pattern of performance puts on models of sentence production, with particular attention devoted to the process of closed-class word retrieval.

Summary of findings

CB's production of words in isolation, or in very short sequences (e.g., NPs), led to similar levels of performance for open- and closed-class words. Overall, the patient's performance was very good in oral and written picture naming, as well as in transcoding tasks—reading and writing to dictation. By contrast, nonword processing was impaired. Nonword repetition was moderately good; nonword reading and writing to dictation led to many errors. Importantly, these errors often shared an important number of segments with the expected target—over 50% in either task. This indicates that sublexical grapho-phonemic conversion procedures are impaired but not totally unavailable.

CB's sentence production was different from his single-word production in important respects. In spontaneous production tasks—e.g., tell

Cinderella's story, construct a sentence from a word—the patient made many more errors in writing than in speaking. These errors for the most part affected closed-class words. In other words, the patient showed a dissociation between word classes in written production that was not observed in his oral production. The same pattern was observed when the patient was asked to write sentences to dictation. Importantly, his difficulties in writing sentences to dictation cannot simply be attributed to the receptive aspects of the task or to difficulties in maintaining a usable representation of the sentence during the course of a trial. CB's sentence comprehension was good: He could read and repeat sentences almost without errors and he had a very good performance in a classic sentence comprehension test. He was also able to repeat almost perfectly the sentences he had trouble writing after he had written them. In spontaneous production and in writing sentences to dictation, the proportion of closed-class word errors increased with the position in the sentence. Finally, in a variant of the verbal span task, CB was asked to write lists of one to five open- or closed-class words from memory. In this task, where no sentence structure was involved, his performance was quite good. Most importantly, it was similar for the two word classes.

Continuous variables and word classes

A basic result concerning CB's performance is the dissociation between open- and closed-class words observed in sentence writing and not in sentence speaking. One classical difficulty when interpreting deficits that selectively affect grammatical categories is the existence of variables that are correlated with membership in a category. For example, closed-class words tend to be more abstract than open-class words—they have less defining features or more variable meanings. Also, closed-class words are on average more frequent and shorter than open-class words. In principle, any of these factors could provide a potential explanation for a dissociation between the ability to produce the words of the two classes. As a first step in understanding CB's deficit, it is important to evaluate the validity of this type of explanation.

An explanation in terms of word frequency cannot explain CB's problems. Word frequency effects are the observation of worse performance—e.g., more errors—on less frequent words. In opposition to that, CB made more errors on the words that are the most frequent, namely closed-class words.

It is also unlikely that the reported deficit is solely due to orthographic properties of closed-class words such as their length. A purely orthographic interpretation of CB's errors would, for example, explain the substitution of the determiner *le* ("the$_{masc}$") for the determiner *ce* ("this$_{masc}$") as a substitution of the first letter of the word. If this were the main origin of CB's errors, his deficit should affect open- and closed-class words similarly. An analysis of his orthographic errors on open-class words shows that this was not the case: Orthographic errors on open class words were very infrequent (e.g., 4/150 words in the spontaneous production task). These errors only occurred on long words of six letters or more. In other words, CB's unbalanced performance between open- and closed-class words cannot be interpreted as a sublexical orthographic deficit. We have also seen that surface similarity (orthographic or phonological) did not provide a reliable explanation of the outcome of CB's closed-class word substitutions. The analysis we conducted in the previous section suggested that the surface similarity between some substituted words was most probably the by-product of within-category substitutions rather than the other way around.

As was mentioned earlier, the meaning of the words on which CB made most of his errors—closed-class words—tends to be rather abstract. It could be proposed that these errors occur because the patient has difficulties in activating a representation of the meanings of closed-class words—an interpretation of the deficit at the level where the message is elaborated. For example, Bird et al. (2002) recently described various patients with deficits affecting the closed class that could be attributed to their difficulties in processing abstract meanings. Class effects disappeared in these patients when psycholinguistic factors such as imageability were controlled for (note that this investigation concerned the production of isolated words, whereas CB's deficit only affects the production of closed-class words in sentences). To argue against this explanation in the case of CB, the modality specificity of his deficit plays a critical role. In most language production models, a *single* semantic system feeds the speaking and the writing systems, regardless of details concerning the organisation of subsequent linguistic processes. Under this assumption, if CB's deficit were purely semantic it should be as visible when he speaks as when he writes. In contrast with this prediction, closed-class word production is preserved in CB's speech (Caramazza & Hillis, 1990). Also, if the origin of CB's deficit were primarily in the semantic system, it could be expected that semantic factors would systematically affect a sizeable part of his substitutions across word categories. Contrary to this expectation, no particular type of information was found to influence open-class substitutions. Determiner substitutions were not primarily due to errors in the processing of the semantic features that contribute to their selection. Hence, the analysis of CB's substitutions does not provide any indication that his errors have originated at the semantic level.

In short, then, the characteristics of CB's performance argue in favour of locating his deficit at a level of linguistic processing that is specific to the writing modality of production rather than to a central semantic processing. Furthermore, the deficit is most likely to involve closed-class words because of their lexical/grammatical status, rather than because of other underlying variables.

Some aspects of the representation of closed-class words in the lexicon

Up to this point, we have characterised CB's written sentence production deficit as affecting the production of *closed-class words*. In fact the expression "closed-class words" regroups a variety of types of words from different grammatical categories, such as determiners, prepositions, auxiliary verbs, etc. Although these words can have very different properties, they are generally grouped together for two main reasons. First of all, closed-class words tend to contribute much more than open-class words to conveying sentential structure in word sequences. Second, words from the open and the closed class tend to behave differently in production errors of normal subjects and aphasic patients (Garrett, 1992).

In the case at hand, the error rate on different types of closed-class words was not completely homogeneous. It was statistically undifferentiated in the spontaneous production task but not in the writing to dictation task. In the latter task, determiners produced a higher error-rate than other categories and conjunctions were overall better preserved. Such small differences across grammatical categories within the closed class might signal relevant underlying processing differences. Besides that, CB's word substitutions most often involved words of the same grammatical category (e.g., determiners replaced determiners, etc.) This constraint could also provide an indication that grammatical class identity per se is a relevant organising dimension of CB's deficit, over and above membership of the closed-class.

Despite these observations, CB's deficit does not provide the best possible data for addressing the issue of processing differences within the closed class. This is because he does not show any strong effect that would allow grouping or distinguishing words of different grammatical categories within the class (Friederici, 1982). Therefore, for the discussion of this study, we will consider the closed class as an undifferentiated set. This position does not prejudge the possibility of showing more fine-grained distinctions between different grammatical categories—for example, but not only, if clear dissociations within the closed-class could be described (see, however, Miceli et al., 1989).

The observation of a deficit restricted to words of certain grammatical categories in one modality of output can be related to previously reported studies of modality-specific dissociations. For example, various patients have been described with dissociations between nouns and verbs restricted to speaking, or restricted to writing (e.g., Caramazza & Hillis, 1991). These deficits have been attributed to damage to representations of the lexical/

grammatical properties of the words the patients have trouble producing. The fact that difficulties arise only in one modality of output further indicates that the deficit affects modality-specific representations. In this scenario, lexemes—phonological or orthographic lexical representations—would be segregated in grammatical categories. A consequence of this is that models of lexical access would not need to postulate an intermediate lexical level of lemmas. This is because the lemma level is, among other things, intended to represent grammatical information separated from modality-specific information (Caramazza, 1997; Roelofs, Meyer, & Levelt, 1998, defend the alternative view that grammatical class deficits restricted to one modality of output are due to an *access* impairment; in this interpretation difficulties in accessing the forms of words of certain grammatical categories would be the consequence of a deficit in the transmission of information from the lemmas of certain grammatical categories to the corresponding lexemes; see discussion in Alario et al., 2003).

At first sight, the case presented here could be taken to provide the same type of evidence for items other than nouns and verbs. Since CB shows a modality-specific deficit affecting a particular class of words—the closed class—we might conclude that the representation of the grammatical identity of closed-class words is closely interrelated with their orthographic—and possibly phonological—representations. However, there is an important difference between the production of nouns and verbs and the production of closed-class words. It is not straightforward a priori that closed-class words will have the same type of lexical representations that have been postulated in theoretical models of language production for the members of the open class. This is because closed-class word production is often thought to be closely tied to syntactic operations (e.g., Garrett, 1975) and because the selection of these words is not necessarily driven by semantic information (Levelt, 1989). In the following section, our discussion of the representation and retrieval of closed-class words will therefore be made in the context of models of sentence production, rather than models of single word lexical access.

Closed-class word retrieval during written sentence production

Garrett's model of sentence production is an account of oral production processes. In order to interpret CB's deficit, it is necessary to extend these models of oral production to the written modality. In the Introduction we briefly described such an extension. In the view we put forward (see also Rapp & Caramazza, 1997), the functional level is thought to be modality independent. At this level, the same processes and representations are used for oral and written production. The sentence frames that are retrieved at the subsequent positional level were also presented as modality independent. That is, the same frames are used for speaking and for writing. What differs between the two modalities of output are the processes of open-class lexeme insertion and the process of closed-class word form retrieval. Modality-specific processes, different for open- and closed-class words, allow the retrieval of word forms during speaking and during writing.

In the oral production tasks CB made very few errors and these errors did not affect selectively the members of the open or the closed-class. Most importantly, the syntactic structures of the sentences he produced were perfectly normal, if not very complex. In written production, where the patient made many errors on closed-class words, the sentence structures that he used also appeared to be largely intact. In fact, most of his sentences—including those in which there were errors—were properly constructed. Beyond a qualitative assessment, this claim is supported numerically by the results of the quantitative analysis of his spontaneous production (Saffran et al., 1989). In other words, sentence frame processing appears to be intact, both for oral and for written production, while the processing of the orthographic form of closed-class words is impaired.

The fact that the processing of the orthographic forms of closed-class words can be damaged independently of frame processing favours the view that sentence frames do not include the forms of closed-class words (in line with Garrett, 1984). Otherwise, these two types of representation should not be damageable separately. Also, these results are fully compatible with the view described earlier that sentence encoding makes use of the same "amodal" frames during oral and written production. The hypothesis of a specific deficit of closed-class word-form retrieval also accounts for the case of PBS we mentioned previously (Rapp & Caramazza, 1997). This patient made most of his errors on open-class words during oral production and on closed-class words during written production. The authors argued that his syntactic processes—including sentence frame retrieval at the positional level—were preserved. His written output deficit would be explained by a deficit similar in nature to CB's. His oral deficit would be explained by problems with the retrieval of the phonological forms of open-class words (see Rapp & Caramazza, 1997, for details; see also Nespoulous et al., 1988).

By contrast, the Case 1 described by Miceli et al. (1983) is difficult to account for in the context of modality-independent frames and modality-specific closed-class retrieval processes. This patient produced oral agrammatic speech: errors on closed-class words and, importantly, very fragmentary sentences. Accordingly, the authors' explanation of his deficit highlights the syntactic nature of the disturbance. Within the context of the hypotheses advanced to account for CB's deficit, this pattern could be explained by postulating a deficit at the level of sentence frame retrieval—and possibly a deficit of the retrieval of the form of closed-class words. What is difficult to explain is the fact that this patient's written production was entirely normal. In our hypotheses, written production is dependent on the same amodal sentence frames as oral production, that is to say, if they are available for written production they should also be available for oral production. Since in this patient positional frames were readily available for writing but deficient for speaking, it could be the case that different representations must be used in the oral and the written modality. In this view, sentence construction for writing would require the retrieval/construction of sentence frames that are specific to this modality.

In short, then, the case presented here, as well as the results reported in some other studies, favour the view that sentence frame retrieval and closed-class word retrieval are distinguishable processes. This interpretation is in line with the assumptions made by Garrett (1984). Furthermore, closed-class word retrieval would be a modality-specific process. As a secondary point, we have noted that in Miceli et al. (1983), Case 1 could provide evidence in favour of modality-specific positional frames. This hypothesis is not part of our explanation of CB's deficit; however, adopting it would not modify greatly the accounts given for CB (the case presented here) and PBS (Rapp & Caramazza, 1997). It is excluded from our interpretation for the sake of parsimony and because in CB—as well as in PBS—syntactic processes appear to be intact. In this modified view various processes/representations are postulated to be modality specific and "redundant": sentence frame and closed-class retrieval. This position has the advantage of accounting for the various patients discussed here (including Case 1 of Miceli et al.). However, it is clear that its explanatory power comes in part from its degrees of freedom. This hypothesis should, then, be considered cautiously.[10]

Producing words in isolation and in sentences: Information summation and lexical retrieval

Under the interpretation proposed in the previous section, CB's deficit affects the retrieval of the orthographic representations of closed-class words. This could suggest that the patient will have difficulties writing words of this class whatever their context of occurrence, and not only during sentence production. We have seen that this is not the case: Open- and closed-class words lead to similar levels

[10] It is possible that oral and written production cannot be compared on representational issues as directly as we have done. A full discussion of some modality-specific dissociations might require a detailed theory of the differences of cognitive performance of speaking and writing. Such a theory can only come from a more extensive study of various types of modality-specific deficits affecting sentence production.

of performance in the production of single words and the production of lists of unrelated words.

According to writing models, several routes can be used for writing words to dictation (Rapp, Epstein, & Tainturier, 2002). The first one is the lexical route—the dictated word activates its representation in the lexicon, which in turn activates the appropriate orthographic information. The second one is the sublexical conversion route—the phonological input is converted into orthographic information by following sublexical regularities. This is the route that allows the writing of nonwords. In the case of CB, both processing routes seem to be impaired. According to the interpretation given in the previous section, CB makes errors on closed-class words because of a deficit in the retrieval of the orthographic lexical closed-class items (or simply put, because of damage to the lexical route). We also know, from the fact that he makes many errors when writing nonwords, that his sublexical conversion route is impaired. Despite these two (partial) deficits, CB's preserved ability to write open- and closed-class words in isolation or in unrelated lists can be explained by postulating a summation of information gathered from both routes (Hillis & Caramazza, 1991; Patterson & Hodges, 1992; Rapp et al., 2002). The summation hypothesis proposes that, when available, a combination of partial information gathered through the lexical route and partial information gathered through the sublexical route allows correct retrieval and production. This proposal was originally made to explain a range of facts about lexical selection of open-class words (and particularly the ability to read irregular words that are not comprehended, Patterson & Hodges, 1992). It can be extended to account for the production of closed-class words in isolation by the patient CB.[11]

But why does the task of writing sentences to dictation lead to a dissociation between open- and closed-class words that is very much like the one observed in spontaneous production? The dictated sentence provides all the necessary phonological information that would be required to feed the—partially deficient—sublexical conversion route. Furthermore, CB was able to recall orally the sentences on which he produced errors.

Writing a sentence to dictation requires maintaining a larger amount of information than writing a single word. Various types of coding contribute to the ability to remember a sentence for the duration of the writing process (e.g., semantic, syntactic: Butterworth, Shallice, & Watson, 1990). In addition, a coding at the word or phonological level probably occurred, since CB was able to repeat sentences word by word and not just their gist. This multilevel encoding implies that writing a sentence to dictation does not need to be the simple transcription of a sequence of phonemes. That is, the task critically involves information other than the phonological representations of words. In line with the previously described summation hypothesis, the various types of information that participate in sentence memorisation (e.g., syntactic and semantic representations) could contribute to the retrieval of orthographic information. The availability of this type of information would shift the balance between phonological, lexical, and structural factors in lexical processing and in closed-class word retrieval. In other words, when CB is writing a sentence to dictation, the relative importance of the different types of information that can be involved in the retrieval of closed-class words is different from when he writes words in isolation.[12] His closed-class word retrieval is in important respects supported by a structural representation

[11] The original summation hypothesis proposes a summation between information gathered through sublexical conversion processes and through the lexicon. As has been noted earlier, the status of the lexical representation of closed-class words is still undetermined. Therefore, the summation that is proposed here could involve some kind of semantic or word-identity information, irrespective of its actual "lexical" implementation.

[12] The proposal of a variation of the importance of structural and phonological information that depends on the task could be seen as an ad hoc position motivated by its ability to account for the data. Alternatively, this hypothesis might be taken only as a particular way of implementing the generally entertained idea that processing words in isolation is much less dependent on syntactic/grammatical processes than processing words in sentences.

of the sentence to be produced (see discussion below).

The interpretation proposed here is supported by the fact that writing an unstructured list of words does not lead to a difference in performance between open- and closed-class words. It is also compatible with the observations reported by Nespoulous et al. (1988). When the patient they described—Mr Clermont—was asked to read sentences written vertically one word below the other, the patient read the words appropriately (even closed-class words) up to the point where he realised he was reading a sentence. At that moment, he started reading the sequence "as a sentence," thus producing his usual pattern of closed-class deficit. This shift of behaviour can be interpreted as the consequence of the triggering a "sentence production mode" where nonsurface levels of processing play a critical role.

Some recently reported cases provide evidence for a role of *syntactic structure* on lexical retrieval. Critically, these patients' performance in the production of certain types of words improves by the provision of syntactic information. Druks and Froud (2000) present the case of a deep dyslexic patient who has a selective closed-class word reading deficit. The authors argue that this deficit can be related to the grammatical identity of closed-class words, rather than to the abstract character of these words or to the difficulties the patient also has for writing nonwords (see Druks & Froud, 2002, for details). This patient's reading of closed-class words improved significantly when the words were read in sentences. This improvement is attributed to the syntactic information carried by the sentence context. Similarly, Berndt and Haendiges (2000) describe a patient with a deficit in speaking and writing verbs, compared to speaking and writing nouns. Verb production performance improved when the patient was provided with syntactic information—a sentence preamble that constrained the word category of the response. By contrast, providing semantic information in the form of a short definition had no effect on verb selection. This effect was also explained by the authors in terms of a role played by syntactic information in word retrieval.

The interpretation of the performance of these two patients underlines the importance of modelling the role of syntactic structure in word retrieval. Note, however, that the interpretation proposed here for CB's impairment contrasts with the cases described by Druks and Froud (2002) and by Berndt and Haendiges (2000) in at least two respects. First of all, in CB's case the impairment would be due to a deficient activation of closed-class items by an appropriately retrieved sentence structure. In other words, the activation process that allows performance improvement in the patients described by Druks and Froud and by Berndt and Haendiges would be impaired in CB. Second, we have not specified in a detailed way the nature of the structure involved in supporting word retrieval during written sentence production.[13]

Finally, we can note at a more general level that the role of sentence structure for word retrieval does not need to be homogeneous across lexical categories. For instance, there could be important differences in the role of sentence structure in the retrieval of verbs and closed-class words. These differences could be tied to systematic differences in the role of the different sources of information—particularly structural information—during lexical retrieval in automatic sentence encoding (Druks & Froud, 2002). A principled and detailed specification of the balance between the different activation sources would provide a valuable support for the hypothesis discussed here.

The linearisation of word sequences: Effect of word position on closed-class errors

One final aspect of CB's performance needs to be discussed. An analysis of his errors in sentence

[13] In spite of this under-specification, it can be noted that CB's substitutions were not simply explainable by surface similarity or by semantic factors. Therefore, this structure is probably not only a phonological representation of the sentence to write or of its semantic specification. Otherwise its defective support to the orthographic retrieval process should yield a larger proportion of semantic or surface (orthographic/phonological) errors.

writing revealed an increasing linear relationship between the error rate on closed-class words and the position of these words in the sentences (see Table 8 and Figure 2). This relationship was observed in all the tasks in which the dissociation between open- and closed-class words was observed: spontaneous production, sentence construction from a single word, and writing to dictation. In the previous sections, CB's pattern of performance was interpreted as a consequence of his deficit in activating the orthographic form of closed-class words. Within the general framework of Garrett's (1975) sentence production model, our interpretation locates CB's deficit at the *positional level* of sentence processing, the level at which word order is specified. The observation that the error rate on closed-class words is sensitive to a parameter like sentence position suggests that word order is already specified at the level where these errors are arising. In other words, within a Garrett-like model the position effect on error rates provides an additional argument for our interpretation of the locus of CB's deficit. What would remain to be explained is why the relationship between error rates and sentence position followed an increasing linear trend, rather than other possible systematic relationships. Although it is not possible to give a definite interpretation of this phenomenon, we discuss below some tentative explanations for this observation.

One classic interpretation of linear position effects relates them to the retrieval of information from an ordered short-term memory device. For instance, in the single-word writing literature there are many cases of impairment to the so-called *graphemic buffer*, a structure devoted to keeping letter sequence information ready for overt execution (Caramazza & Miceli, 1990). Deficits to this buffer can lead to an increasing number of errors at the ends of words. The pattern is explained by the fact that letters at the end of words have to stay longer in the buffer and therefore are more susceptible to decay in the case where the buffer is impaired (Schiller, Greenhall, Shelton, & Caramazza, 2001). In principle, it could be proposed that CB's errors on closed-class words arise because of a similar phenomenon—prior to overt execution the encoded sentence would be temporarily stored in an impaired buffer. The retrieval from this buffer would be sensitive to sentence position. Note, however, that for this explanation to work, the short-term memory structure in which the sentence is stored—and where decay of closed-class information happens—would not be the graphemic buffer. This is because even if this device codes much more than the simple sequence of letters to be produced, it does not code information such as grammatical class. If a short-term buffer is postulated to store the sequence of syntactically specified words, then it would have to lie somewhere between the processes of lexical retrieval and graphemic specification. To know whether or not such a buffer is a requirement for models of written production would require a specific investigation.

Alternatively, the linear position effect could be related to earlier processes of lexical retrieval and frame insertion rather than to the (later) retrieval of an encoded sentence from a short-term storage buffer. In the previous sections, we have argued that an (ordered) sentence structure played a central role in closed-class retrieval during sentence encoding in this patient. According to this interpretation, closed-class words would be retrieved sequentially in the order specified by the sentence structure. The linear position effect can be explained if the activation produced by the sentence frame for lexical retrieval at the end of the sentence were less efficient than it is at the beginning of the sequence. One possible implementation of this general idea could be based on Kolk's (1995) time-based interpretation of agrammatic production. In this theory, closed-class deficits are to due to a disruption of the temporal fine tuning between the availability of sentence frames and the process of lexical retrieval. Errors occur because of a lack of synchronicity between the two processes, which prevents lexical insertion from happening: Frames might become available during a time window when lexical items are not and/or vice-versa. Applying this type of explanation to CB's performance is possible if we make the plausible assumption that synchronicity between frame retrieval and lexical access is better at the beginning of a sequence than at the end of sentences.

Clearly, the discussion of the error position effect made in this section is very speculative. We have seen that various types of explanations could account for this effect, and that the data we present are not able to distinguish between them. However, irrespective of the detailed processing account of the effect, what is important for our purposes is the sensitivity of closed-class word retrieval to sentence position. This observation argues in favour of localising CB's deficit at the positional level during sentence production. It further underlies the role of a sentence level structure in the retrieval of these words.

CONCLUSION

We have reported the case of a patient (CB) who, following CVA, suffered from a modality-specific disruption of closed-class word production. When asked to write sentences in a variety of tasks, CB produced many more errors on closed-class words than on open-class words. This difference was not observed in tasks requiring the written production of isolated words, or in speech production tasks. The results of the experimental investigations indicated that CB's deficit is most likely to be located at a level where orthographic lexical representations are retrieved, rather than at a more central semantic level or at the processing of the surface properties of orthographic representations. The nature of this deficit has been discussed in the context of the processes of sentence encoding and sentence production. CB's performance favours the idea that sentence frame retrieval/construction and closed-class form retrieval are distinct process, since they can be damaged separately. Still, it is likely that sentence structure, once it is constructed, plays a critical role in the retrieval of these words. The exact nature of the structure involved in lexical retrieval and the role played by structural information in this process awaits further clarification.

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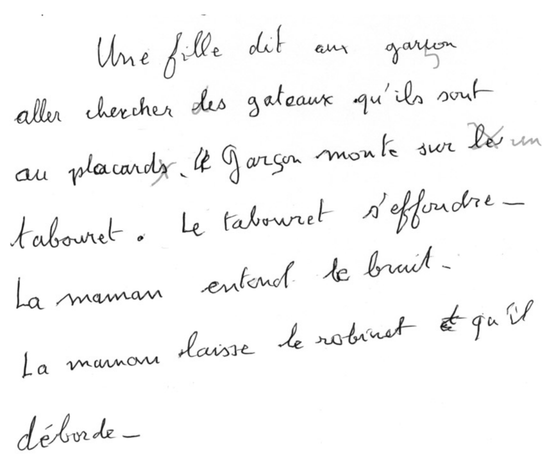
APPENDIX A

Examples of CB's performance in various writing tasks

The English translation can only be indicative, since it is difficult to translate erroneous productions while keeping the nature of the error faithful to the original production. Errors: morph = morphological; phon = phonological; orth = orthographic; miss = missing item; inapp = inappropriately used item.

Picture description (cookie theft, BDAE)
Sentences produced



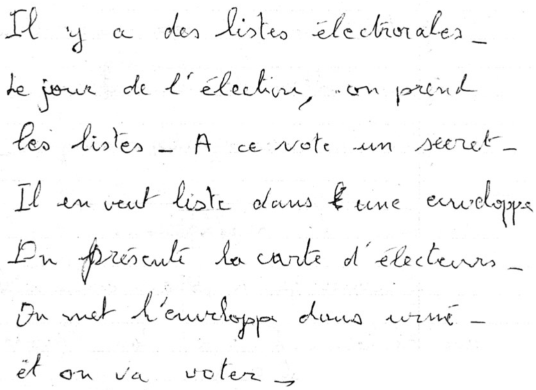
Transcription
Une fille dit au**x**$_{morph}$ gar**c**on$_{orth}$ [**d'**$_{miss}$] aller chercher les **ga**teaux$_{orth}$ qu'**ils**$_{inapp}$ sont **au**$_{inapp}$ placard**s**$_{morph}$. Le garçon monte sur le tabouret. Le tabouret s'effondre. La maman entend le bruit. La maman laisse le robinet **qu'**$_{inapp}$ **il**$_{inapp}$ déborde.

Approximate English translation
A girl tells to **the**$_{morph}$ **boy**$_{orth}$ [**to**$_{miss}$] go get the **cookies**$_{orth}$ that **they**$_{inapp}$ are **at**$_{inapp}$ the cupboard**s**$_{morph}$. The boy climbs on the stool. The stool collapses. The mother hears the noise. The mother lets the faucet **that**$_{inapp}$ **it**$_{inapp}$ overflows.

French corrected version
Une fille dit au garçon d'aller chercher les gâteaux qui sont dans le placard. Le garçon monte sur le tabouret. Le tabouret s'effondre. La maman entend le bruit. La maman laisse que le robinet déborde.

Comments
The annotations in grey are the patient's self-corrections. Across tasks, only his first production is scored. This production was slow and careful. On average, self-corrections did not improve the content of the writing.

Spontaneous production (what happens on election day?)
Sentences produced



Transcription
Il y a des listes électrorales$_{orth}$. Le jour de l'élection, on prend les listes. **A**$_{inapp}$ **ce**$_{substit}$ vote [**est**$_{miss}$] **un**$_{inapp}$ secret. **Il**$_{substit}$ **en**$_{substit}$ **veut**$_{substit}$ liste dans une enveloppe. On présente la carte d'électeur**s**$_{morph}$. On met l'enveloppe dans [**l'**$_{miss}$] urne. et on **va**$_{substit}$ voter.

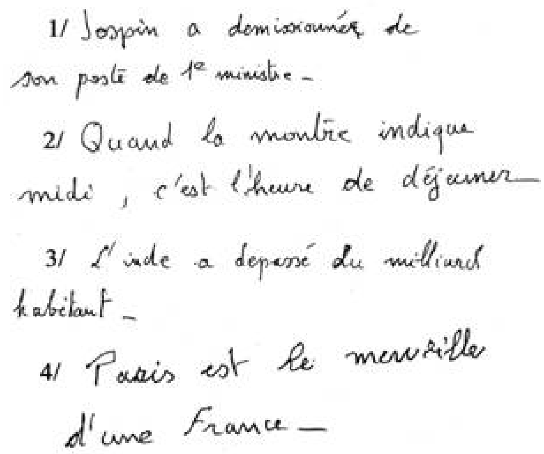
Approximate English translation
There are electroral$_{orth}$ lists. The day of the election (i.e., *on election day*), one takes the lists. **To**$_{inapp}$ **this**$_{substit}$ vote [**is**$_{miss}$] **a**$_{inapp}$ secret. (interpreted as "*the vote is secret*"). **He**$_{substit}$ **in**$_{substit}$ **wants**$_{substit}$ (interpreted as "*one puts a list…*") list in an envelope. One presents his card of elector**s**$_{morph}$. (i.e., *his voting card*). One puts the envelope in [**the**$_{miss}$] urn. and one **goes**$_{substit}$ voting (interpreted as "*one has voted*").

French corrected version
Il y a des listes électorales. Le jour de l'élection, on prend les listes. Le vote est secret. On met une liste dans une enveloppe. On présente la carte d'électeur. On met l'enveloppe dans l'urne. Et on a voté.

Comments
When the production is ambiguous (can be interpreted in several ways), the interpretation that leads to the smallest number of errors has been retained.

Sentence construction from a word
Words given
1. Jospin (former French prime minister)
2. montre (watch)
3. Inde (India)
4. Paris

Sentences produced



Transcription
1. Jospin a demissionné$_{accent}$ de son poste de 1er ministre.
2. Quand la montre indique midi, c'est l'heure de déjeuner
3. L'inde a depassé$_{accent}$ **du**$_{substit}$ milliard [**d'**$_{miss}$] habitant[**s**$_{miss}$].
4. Paris est **le**$_{substit}$ merveille d'**une**$_{substit}$ France.

Approximate English translation
1. Jospin has resigned from his position as prime minister
2. When the watch indicates noon, it is the time for lunch
3. The india has passed **of**$_{substit}$ billion [**of**$_{miss}$] inhabitant[**s**$_{miss}$]. (note: the use of the determiner in front of a country name is correct in French)
4. Paris is **the(masc)**$_{substit}$ wonder of **a**$_{substit}$ France

French corrected version
1. Jospin a démissionné de son poste de 1er ministre.
2. Quand la montre indique midi, c'est l'heure de déjeuner
3. L'Inde a dépassé le milliard d'habitants.
4. Paris est la merveille de la France

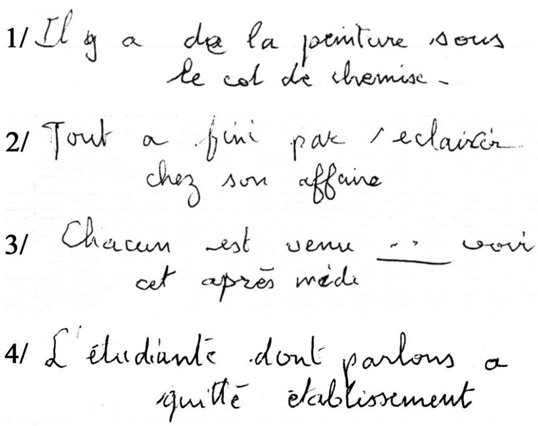
Comments
Sentences 1 and 2 do not have errors. They are presented as examples of correct productions. *Accent* refers to accent errors (minor orthographic deviation).

Writing to dictation

Dictated

1. Il y a de la peinture sur le col de ta chemise
2. Tout a fini par s'éclaircir dans cette affaire
3. Quelqu'un est venu vous voir cet après-midi
4. L'étudiant dont nous parlons a quitté l'établissement

Sentences produced



1/ Il y a de la peinture sous le col de chemise.

2/ Tout a fini par ' eclaircir chez son affaire

3/ Chacun est venu __ voir cet après midi

4/ L'étudiante dont parlons a quitté établissement

Transcription

1. Il y a de la peinture **sous**$_{substit}$ le col de [**ta**$_{miss}$] chemise
2. Tout a fini par [**s**$_{miss}$]'**é**claircir$_{orth}$ **chez**$_{substit}$ **son**$_{substit}$ affaire
3. **Chacun**$_{substit}$ est venu ___[**vous**$_{miss}$] voir cet après midi
4. L'étudiant**e**$_{morph}$ dont [**nous**$_{miss}$] parlons a quitté [**l'**$_{miss}$] établissement

Approximate English translation

1. There is paint **under**$_{substit}$ the collar of [**your**$_{miss}$] shirt
2. Everything has finished by clarifying **at**$_{substit}$ **his**$_{substit}$ business (reflexive pronoun **s'** missing)
3. **Each one**$_{substit}$ has come to ____ see [**you**$_{miss}$] this afternoon
4. The student**(fem)**$_{morph}$ about whom [**we**$_{miss}$] speak has left [**the**$_{miss}$] institution

Comments

The patient repeated every sentence orally just after he had finished writing it. In the examples presented above, he was flawless at this repetition, except for one (phonological) error on the word "*student*" (sentence 4).