

The Modality-Specific Organization of Grammatical Categories: Evidence from Impaired Spoken and Written Sentence Production

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We describe the case of a brain-damaged individual whose speech is characterized by difficulty with practically all words except for elements of the closed class vocabulary. In contrast, his written sentence production exhibits a complementary impairment involving the omission of closed class vocabulary items and the relative sparing of nouns. On the basis of these differences we argue: (1) that grammatical categories constitute an organizing parameter of representation and/or processing for each of the independent, modality-specific lexicons, and (2) that these observations contribute to the growing evidence that access to the orthographic and phonological forms of words can occur independently. © 1997 Academic Press

Traditionally it has been assumed that written language skills are entirely dependent upon spoken language knowledge and processing. Such an assumption has been made both by those who study individuals with acquired neurological deficits (Brown, 1972; Head, 1926; Geschwind, 1969; Grashey, 1885; Hecaen & Angelergues, 1965; Lichtheim, 1885; Luria, 1966; Wernicke, 1886) as well as by those who study the performance of normal unimpaired subjects (see Frith, 1979; Hotopf, 1980; and Van Orden, Johnston, & Hale, 1988 for a review of the issue in the context of reading). Often associ-

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ated with this assumption (although not required by it) is the view that linguistic features such as grammatical category, morpheme, and syllable, if represented at all at the level of lexical form, are the exclusive domain of phonological form. There is, however, growing evidence that these assumptions are unwarranted. Thus, not only is there increasing evidence that lexical orthographic representations may be accessed without phonological mediation, but also that orthographic representations are complex linguistic objects that include the specification of grammatical category, syllables, morphemes, and subsyllabic components.

Here we will present the performance of a neurologically impaired subject whose speech is characterized by difficulty with practically all words except for elements of the closed class vocabulary. In contrast, his written sentence production exhibits a complementary impairment involving the omission of closed class vocabulary items and the relative sparing of nouns. This pattern of performance will allow us to argue: (1) that access to orthographic (and phonological) lexical forms is realized in a manner that respects *modality-specific* distinctions between the grammatical categories of noun and function word, and (2) that, as a consequence, the observed differences in written and spoken sentence production constitute further evidence that access to orthographic word forms can occur independently of access to phonological forms. Finally, we will point out that the finding of grammatical class effects that are specific to a particular output modality has clear implications for the assessment and interpretation of impaired sentence production.

THE REPRESENTATION OF GRAMMATICAL CATEGORY

Within current theories of lexical and sentence processing, grammatical category distinctions have been posited at multiple levels of representation. In order to provide a theoretical framework for this discussion we will consider and briefly summarize the sentence production framework proposed by Garrett (1980, 1984, 1992; and see Fromkin, 1971; Levelt, 1989, for similar proposals). Within this framework spoken sentence production involves three basic representational and processing stages which are depicted schematically in Fig. 1: the message level, the functional level and the positional level.

Beginning with a message one wishes to communicate involving, for example, a girl eating apples, one uses logical and syntactic processes in order to develop a *functional level representation*. The processes involved in going from the message to the functional level representation include: (a) the selection of the specific lexical items to be used in communicating the content of the intended meaning (e.g., apple, girl, eat) and (b) the development of the argument structure to be used for communicating the message (e.g., verb, noun-agent, noun-object). It is important to note that at this level of representation lexical items are defined by amodal semantic and syntactic properties and *do not have phonological or orthographic content*.

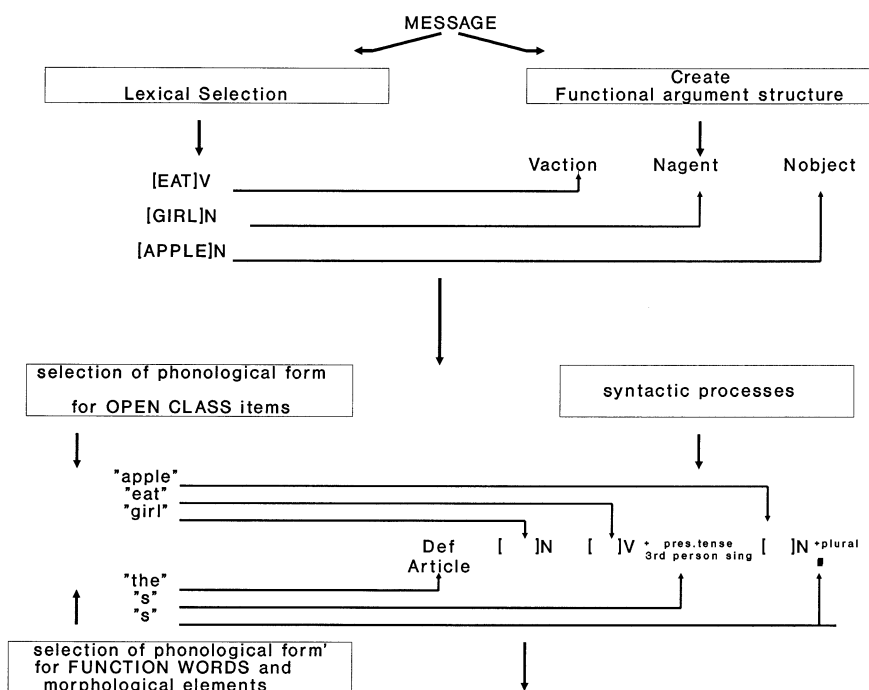


FIG. 1. A depiction of the processes and representations involved in spoken sentence production.

The functional level of representation is then subjected to additional syntactic processes and phonological ones in order to derive a *positional level representation* in which: (a) the arguments are organized into a phrasal tree structure which includes the abstract syntactic features needed to specify the function words (in this example the articles and prepositions) and morphological elements (e.g., verb tense and plural), then (b) the lexical phonological forms corresponding to the open class items are retrieved and assigned to their corresponding positions in the phrasal planning frame, and finally (c) a set of (phonological) processes supply the phonological content for the function words and morphological elements. Thus it is only in the course of developing the positional level of representation that phonological information first becomes available. Subsequent stages involving phonetic and motor processes result in the spoken production of an utterance such as "The girl eats the apples."

Within such a framework grammatical category membership is relevant at multiple levels: (1) at the level of the semantic/syntactic representation of lexical items, (2) in the application of the syntactic rules required for generating the surface phrasal geometry of the positional frame, and (3) addi-

tionally, grammatical category membership is respected by the procedures responsible for assigning phonological content to the planning frames used in speech production. Specifically, distinct procedures supply the phonological form of content words vs. function words and morphological elements to the positional frame.

On the basis of proposals such as this one, we should expect to find impairments that are sensitive to grammatical category distinctions arising from damage to quite different levels of representation/processing. In fact, there have been a number of cases of selective deficits affecting a variety of grammatical categories: nouns (Miceli, Silveri, Villa, & Caramazza, 1984; Miceli, Silveri, Nocentini, & Caramazza 1988; Damasio & Tranel, 1993; Zingeser & Berndt, 1988; Hillis & Caramazza, 1995), verbs (Caramazza & Hillis, 1991; Miceli et al., 1984, 1988; McCarthy & Warrington, 1985; Hillis & Caramazza, in press) proper nouns (Lucchelli & De Renzi, 1992; McKenna & Warrington, 1980; Semenza & Zettin, 1989; Shallice & Kartsounis, 1993), and function words (Andreewsky and Seron, 1975; Gardner & Zurif, 1975; Caramazza, Berndt, & Hart, 1981). The interpretation of many of these cases is limited (for our purposes) by the fact that most were not studied in order to determine the precise locus of the functional deficit. Nonetheless, there is sufficient evidence to indicate a range of functional loci. For example, various *modality-independent* processes have been implicated, among them: a central processing level required for both comprehension and production of verbs (McCarthy & Warrington, 1985); sentence level vs. single word processing of function words (Caramazza & Hillis, 1989); processes shared by both written and spoken naming of nouns (Zingeser and Berndt, 1988). In addition, there is strong evidence of selective grammatical category impairments at the level of *modality-specific* lexical form. Caramazza and Hillis (1991) report the cases of two individuals who show selective deficits to the category of verbs in only one modality of output. Thus, while H.W. produced semantic errors with verbs in oral picture naming and reading (e.g., producing "scramble" for *fry* in spoken output), few such errors were produced for spoken nouns and none in writing nouns or verbs. In contrast, S.J.D. produced semantic errors only in naming verbs in writing¹ (for a similar case see Rapp, Benzing, & Caramazza, 1994).²

A framework such as the one presented in Fig. 1 naturally accommodates both the modality-independent and the modality-specific deficits. In the context of single word production, deficits involving amodal aspects of representation/processing can be localized to the abstract specification of the

¹ This pattern of results was also obtained using homonyms in noun and verb contexts: There's a *crack* in the mirror./ Don't *crack* the nuts in here.

² Lest one think that these effects are attributable to some greater intrinsic difficulty of verbs, there is the case of E.B.A. (Hillis & Caramazza, 1995) who showed specific difficulties in the oral vs. written processing of nouns relative to verbs.

semantics and syntax of lexical items. In the context of sentence production, modality independent deficits might additionally involve processing and representation up to, and including, the development of the surface phrasal geometry of the positional frame. In contrast, deficits selectively affecting one grammatical category in only one output modality can only be attributed to stages responsible for the specification of modality-specific lexical forms. It is these modality-specific, grammatical category deficits which will form the focus of this investigation.

Although, as we have indicated, there have been a number of cases involving selective deficits to grammatical categories, reports of cases involving modality-specific grammatical-category impairments are relatively rare. In fact, the reports of Caramazza and Hillis (1991), Hillis and Caramazza (in press), and Rapp, Benzing, and Caramazza (1994) constitute the only detailed cases of modality-specific noun/verb dissociations that we are aware of. In addition, however, there is also evidence of modality-specific effects involving the class of function words. Early indications of such cases can be found in Lecours and Rouillon (1976) and Lhermitte and Derouesne (1974). These authors described individuals exhibiting fluent spoken production with neologisms with relatively well-preserved albeit agrammatic written production. Lecours and Rouillon (1976) mention that, in contrast to their fluent speech, in the writing of certain individuals "a caricatural dissociation sometimes emerges between lexical richness and syntactical decay" (p. 128).

Assal, Buttet, and Jolivet (1981) presented the first detailed study of a patient that was "oral Wernicke vs. written Broca" stating that "verbal expression was slow, poor in vocabulary (especially for names) but rich in grammatical words . . . in contrast to the verbal modality, the written modality showed constant agrammatism: only the use of names of objects came fairly easily." The authors report that the patient had difficulty in producing function words in writing sentences to dictation and in spontaneous narrative writing as indicated by the fact that his written responses consisted almost exclusively of nouns. Furthermore, when asked to write homonyms involving noun/function word pairs such as "il" (he) and "ile" (island) or "ton" (your) and "thon" (tuna), he was only able to write the nouns; this in spite of the fact that the function words were of far greater frequency than the nouns (for apparently similar cases see also Bub & Kertesz, 1982; Coslett, Gonzalez-Rothi, & Heilman, 1984; and Patterson & Shewell, 1987). Interestingly, the reverse pattern of performance—"spoken Broca's and written Wernicke's"—although it has not been described in detail is alluded to by Lecours and Rouillon (1976) who note that ". . . when written agrammatism is not apparent, which is not so infrequent, samples of written language in certain cases of Broca's aphasia cannot be distinguished, on linguistic criteria, from samples of written language in certain cases of Wernicke's aphasia" (p. 139).

The modality-specificity of these deficits is extremely interesting because

it allows considerable confidence regarding the functional locus of impairment: the restriction of the effects to a particular modality rules out a more central deficit to the amodal semantic/syntactic representations and procedures thought to be common to both written and spoken production either of single words or sentences. That is, if a grammatical category were selectively affected at an amodal level of representation we would expect both written and spoken production to be impaired with elements of that category. Instead, in these cases we observe dissociations across modalities. Furthermore, because these deficits involve specific grammatical categories a post-lexical locus is unlikely since it is not obvious how more peripheral levels of representation and processing would be sensitive to grammatical category distinctions. Therefore, such deficits can be localized to modality-specific levels of lexical representation/processing.

Given their lexical locus, the modality-specific, category-specific deficits constitute clear (and perhaps unexpected) evidence that grammatical category distinctions among (at least) the categories of function words, nouns, verbs are present *both* in the specification of phonological forms as well as in the specification of orthographic forms. The reasoning is as follows: If grammatical category distinctions were present only at abstract levels of representation and processing—such as at the level of abstract lexical specification—then when we observe damage to one grammatical category in one modality we should also expect to observe it in the other (Fig. 2a). Alternatively, if grammatical category distinctions are respected only by the modality specific procedures responsible for the assignment of phonological form, then we could expect either to observe the same dissociation in orthography as in phonology—if orthographic specification is dependent on prior phonological retrieval (Fig. 2b)—or if orthographic specification can occur independently of phonological processes—that deficits in written production should not respect grammatical category distinctions of any sort (Fig. 2c). However, the observation of complementary grammatical category effects across the two output modalities would indicate that grammatical category information is represented *redundantly* by both sets of modality-specific representations and/or processes (Fig. 2d). We will take up this point again in the Discussion.

ORTHOGRAPHIC AUTONOMY VS. PHONOLOGICAL MEDIATION

From this discussion it is apparent that in addition to their relevance to the issue of grammatical category representation, the modality-specific, category-specific deficits constitute evidence in support of the more general claim that phonological mediation is not required to relate orthographic knowledge with the more abstract aspects of lexical knowledge (such as meaning and syntax). We shall refer to this view as the *Orthographic Autonomy Hypothesis* and it is depicted in Fig. 3. This hypothesis stands in contrast

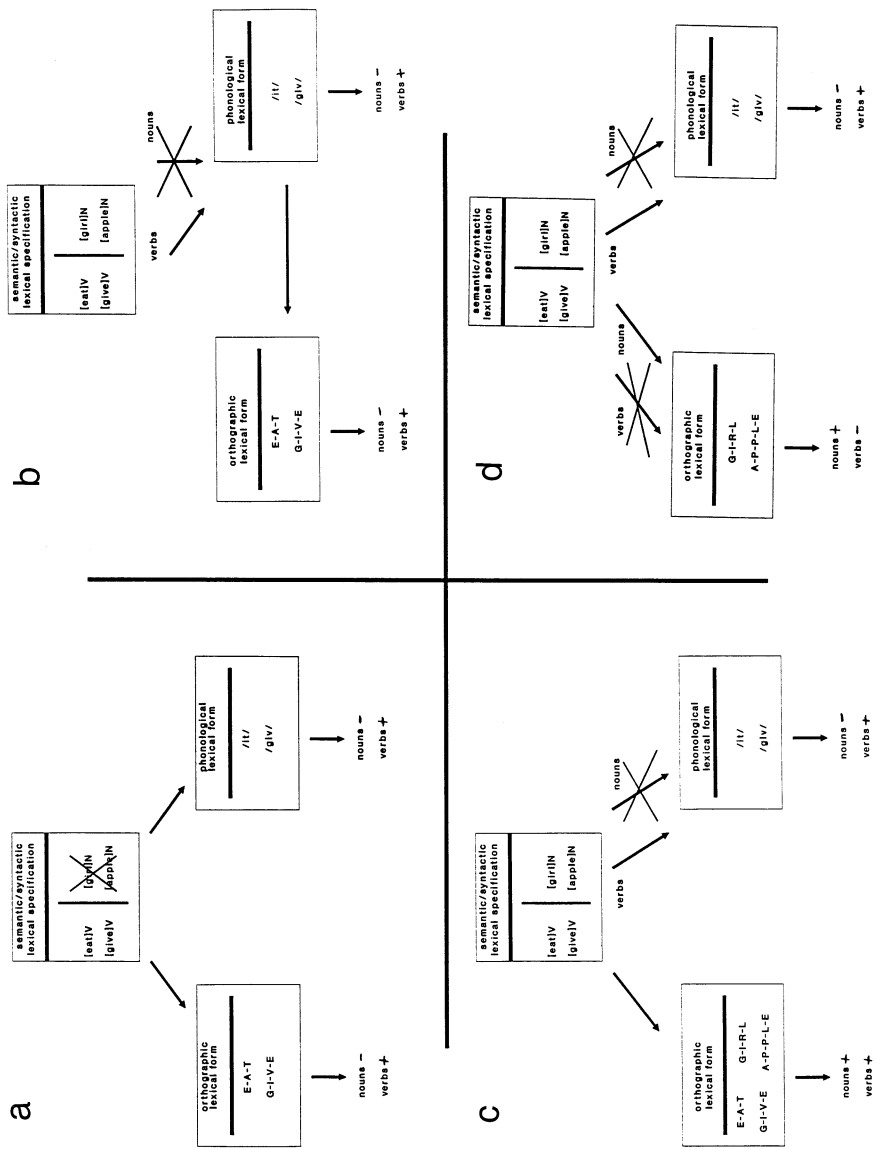


FIG. 2. Different possible loci of grammatical-category effects and the predicted pattern of written and spoken responses for each.

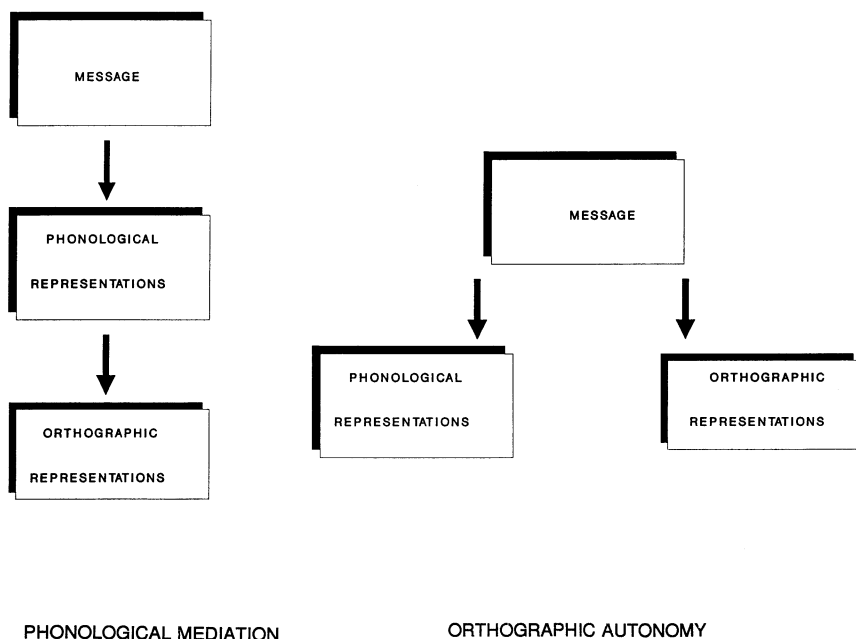


FIG. 3. A schematic depiction of the output processes proposed under the hypotheses of PHONOLOGICAL MEDIATION and ORTHOGRAPHIC AUTONOMY.

with the claim that access to the spelling of a word for the written communication of an intended message necessarily requires the prior retrieval of the corresponding phonological form—the *Phonological Mediation Hypothesis* (see Fig. 3).

There are a variety of patterns of performance that are relevant to distinguishing between these two hypotheses and the one which we will be specifically concerned with here (because of the nature of the errors produced by the subject of this report) involves individuals with relatively spared written performance in the face of speech that is characterized by neologisms and phonemic errors (see also Alajouanine & Lhermitte, 1960; Assal et al., 1981; Basso, Taborelli, & Vignolo, 1978; Caramazza, Berndt, & Basili, 1983; Ellis, Miller, & Sin, 1983; Hier & Mohr, 1977; Lecours & Rouillon, 1976; Lecours, 1982; Leischner, 1969; Lhermitte & Derouesne, 1974; Miceli & Caramazza, 1993; Mohr, Sidman, Stoddart, Leicester, & Rosenberger, 1973; Mohr, Pessin, Finkelstein, Funkenstein, Duncan, & Davis, 1978; Patterson & Shewell, 1987; Semenza, Cipelotti, & Denes, 1992). Thus, whereas fluent, well-articulated neologistic spoken output is often accompanied by neologistic writing, there are striking cases involving preserved written output. For example, one of the French-speaking subjects, described by Lhermitte and Derouesne (1974) when asked to repeat and write the word “poulet,” responded orally

by saying "malcria" but wrote *poulet* correctly or asked to repeat "tambour" he said "moscriba" but wrote *tambour* (for similar examples in English and Italian see also Caramazza et al., 1983 and Semenza et al., 1992). Cases such as these are problematic for the phonemic mediation claim since it is difficult to argue that well-articulated spoken neologistic responses such as those described here form the basis for the retrieval of correct written responses; that is, it is hard to imagine how the phonological representations that support incorrect spoken responses (such as "malcria") would also allow access to correct orthographic representations (such as *tomate*) (Lhermitte & Derouesne, 1974).

However, the uncertainty regarding the functional origin of neologisms (see Buckingham & Kertesz, 1976; Butterworth, 1979; Ellis et al., 1983) leaves these data open to alternative interpretations. Thus, one could argue that in spite of the intact articulatory abilities of these individuals, the neologisms arise from a deficit before the level at which the articulators are engaged and yet beyond the stage at which lexical phonological representations are retrieved. If such were the case then it could be that, in fact, intact phonological representations serve as the basis for the retrieval of the correct orthographic descriptions and that it is some subsequent deficit, specific to the phonological output system, that is responsible for the spoken neologisms. Such an account would render these cases irrelevant to the issue of phonemic mediation. However, this possibility is not easy to assess because accounts of the nature of post-lexical/pre-articulatory mechanisms have not been formulated so as to allow for clear predictions regarding the range and characteristics of errors that should result from damage at these levels of processing. Nonetheless, Butterworth (1979, 1992) has suggested that damage to post-lexical procedures should result in performance patterns involving such things as: systematic difficulties with particular phonemic distinctions, greater numbers of errors for longer than shorter words and lack of sensitivity to lexical factors such as lexical frequency and, presumably, grammatical category. On the basis of considerations such as these³ Butterworth has attempted to differentiate between cases of neologistic production that can be attributed to failures of retrieval of lexical phonological forms (Butterworth, 1979; Panzeri, Semenza, & Butterworth, 1987) and others in which post-lexical processes have been affected (Caplan, 1987; Pate, Saffran, & Martin, 1987).

In sum, to the extent to which a lexical locus of neologistic spoken production is supported, the co-occurrence of neologistic speech and relatively pre-

³ Butterworth (1992) distinguishes between deficits of storage vs. deficits in the transmission of stored information. He argues that consistency in errors is required for establishing a deficit to stored lexical representations. We argue in Rapp and Caramazza (1993) that the use of a consistency criterion for distinguishing between deficits of access vs. storage is dependent upon very specific theoretical assumptions regarding the nature of storage and access (or transmission) and cannot be employed in this pre-theoretical manner.

served written production constitutes a strong argument in support of the notion of orthographic autonomy. Clearly, therefore, cases involving the situation in which one grammatical category is unavailable in spoken output but is selectively preserved in writing would seem to be highly problematic for the phonological mediation hypothesis. If, for example, nouns (but not function words) are produced as neologisms in spoken output but are correctly produced in writing one is hard pressed to argue that phonological mediation is required for the retrieval of the orthographic forms corresponding to nouns.

THE CASE AT HAND

The performance of the individual that we describe in this paper appears to bear considerable resemblance to the cases described above involving the modality-specific dissociation of performance with function words and nouns. Thus, P.B.S.'s speech is characterized by difficulty (neologistic production) with practically all words except for function words, while his writing exhibits a complementary impairment that involves the absence of function word vocabulary and the relative sparing of nouns. Thus, the case constitutes an opportunity to carefully document the modality specific aspects of this particular pattern of grammatical category dissociations.

In contrast to the previous reports we focus on spoken and written sentence production instead of single word production. In addition, we primarily report data from tasks such as picture description or story-telling that do not require the language input processing involved in the oral reading and writing to dictation tasks that were emphasized in previous reports. This choice of tasks allows us to circumvent important interpretative difficulties that result from the fact that P.B.S., as well as all of the previously reported patients (except the one described by Bub and Kertesz (1982)) all have had substantive written and spoken language comprehension impairments in addition to their production deficits. Because of the additional comprehension impairments, the grammatical category effects observed in oral reading, repetition, or writing to dictation could have either, or both, an input or output locus.

This focus on sentence production, therefore, places us in a favorable position to consider P.B.S.'s performance within current, multistage theories of sentence planning and production such as the one described above. We will argue that the striking differences we observe in written and spoken sentence production provide support for the view that the retrieval of orthographic lexical representations can occur independently from phonological ones and, furthermore, that there are processes/representations *specific to written sentence production* which are sensitive to grammatical category distinctions such as noun/function word.

CASE STUDY

P.B.S. was a left-handed male with a high school education who, prior to a left hemisphere CVA at the age of 58, worked for a large government

agency. CT scans revealed evidence of a left middle cerebral artery infarction with a large area of hypodensity in the left parietal and posterior frontal and temporal regions that included both Broca's and Wernicke's areas. No mass effects or signs of hemorrhage were present (see Fig. 4). A fall at the time of the stroke produced bilateral hematomas to the frontal bone. There was no evidence of neglect or hemianopia and he was able to write easily. Note that it is unlikely that the pattern of performance reported here is specific to left-handedness given that the subjects described by Assal et al. (1981), Bub and Kertesz (1982), Coslett et al. (1984), and Patterson and Shewell (1987), with apparently similar patterns of performance, were all right-handed. P.B.S. gave his informed consent to participate in the investigation that we describe here. The investigation was carried out between 6 and 12 months post-CVA.

Preliminary Examination

P.B.S.'s speech was fluent and well articulated but largely uninterpretable due to the large number of neologisms that he produced. For example, when asked to read the word CAT, he responded with "/kræt/ that's a /kltstræt/ but I, I, I can't . . . it's strange, it's a strange /kræt/ rat, it's a cat, rat . . . but yet it, it's /bifuzd/ . . . it, it must be part of the /kəzbəl/. I guess that must be it." He exhibited a severe impairment in the spoken production of single words across a variety of tasks such as reading, repetition, and picture naming where his responses were primarily neologisms, typically differing considerably from the phonological form of the intended target. His prosody appeared to be normal. His written naming had a markedly different character from his spoken output. Neologisms were absent and the majority of the responses were either entirely correct or clearly recognizable (e.g., a picture of a pencil → *penicil*).

In addition to his difficulties in production, P.B.S. was also impaired in the comprehension of both spoken and written single words and sentences. He was administered a discrimination task where he was asked to match a spoken or written word to the correct picture with foils representing visually/phonologically similar words. On this task his accuracy was 85% with auditory presentation and 95% with written presentation. In a yes/no auditory lexical decision task his accuracy was only 71% (27/38) with errors distributed comparably across words and nonwords. In a forced-choice written lexical decision task his performance was 100%. On a subset of items from the PPVT where he was presented with a single word and asked to select the corresponding picture from a set of four he was 66% (38/58) correct with auditory presentation and 81% (46/57) with written. A number of his errors involved the selection of semantically related pictures. His comprehension performance improved in a yes/no word-to-picture matching task involving common objects where accuracy was 90% (129/144) with auditory stimuli and 98% (141/144) with written. Again his errors sometimes involved ac-

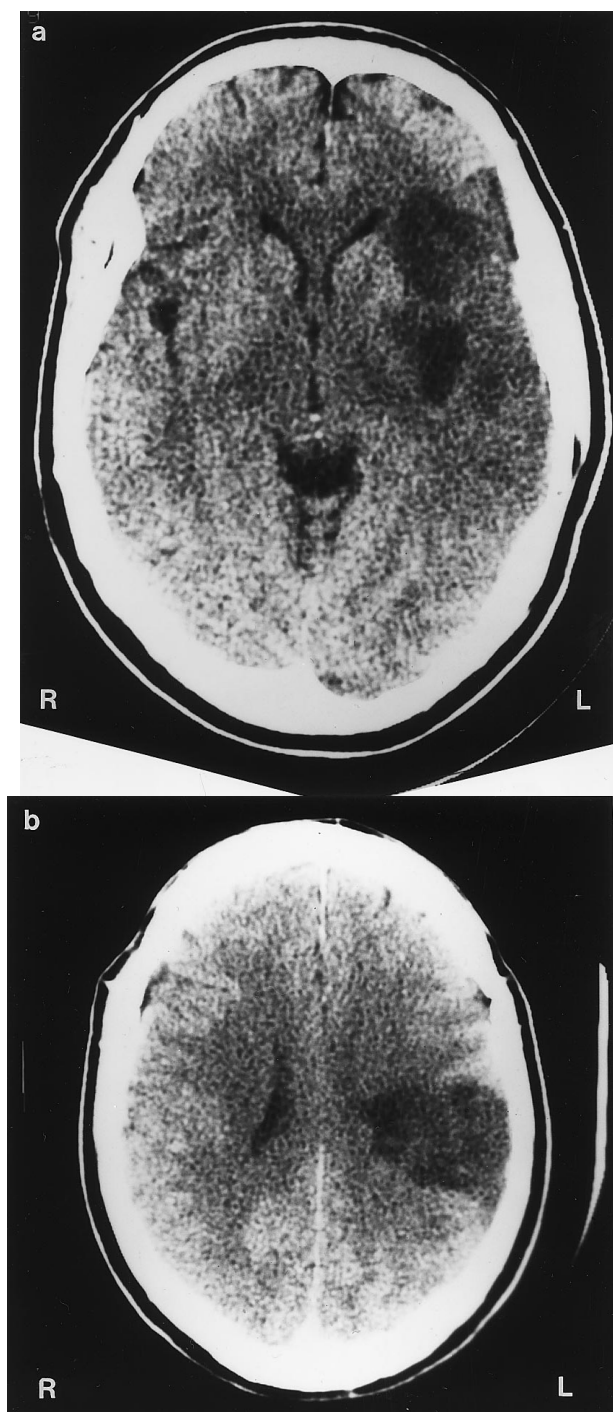


FIG. 4. CT scan of P.B.S. indicating posterior frontal and temporal damage. R, right hemisphere; L, left hemisphere. Top of each scan, frontal; bottom of each scan, posterior.

cepting a semantically related picture (e.g., saying "yes" to a picture of mittens when presented with the word "shirt").

His memory span was measured by presenting concrete nouns to him auditorily and which he then reported in writing. According to this task his span was about two words (10/12 pairs of words were reported correctly).

Given his reduced span as well as the difficulties he exhibited in comprehension at the single word level, it is not surprising that P.B.S. demonstrated significant impairment in sentence comprehension. His ability to detect semantic anomalies (e.g., The athlete devoured his socks) was 87% (13/15) with auditory stimuli and with written stimuli it was 82% (41/50). Judgments of grammaticality were at chance with both auditory and written stimuli—18/37 and 18/35 respectively; his performance in sentence/picture matching with reversible sentences was also at chance—auditory 3/8 and written 5/8 correct.

Although P.B.S.'s written production of single words was markedly superior to his spoken production in object naming, the differences between his written and spoken descriptions of simple scenes could not be characterized as easily. For example, in describing a picture of a rock falling on a car P.B.S. wrote: *car accident rock*. In contrast, in orally describing a picture of a truck crashing into a bus, he said: "The /rʌz/ was a /kəzɒlnd/ at the /drʌʃ/ and he /kræzd/ into his /kard/ and /æz/ /mardʒ/ at the /sard/, at his /kard/, his /kard/." The impression created by his speech was that it contained the syntactic elements as well as the prosody of appropriate sentences (albeit with very few recognizable content words), while his writing contained content words but lacked sentence structure. Thus, while his spoken output provided the surface features of seemingly intact syntactic processing and function word vocabulary, his written production exhibited difficulties with just these aspects of sentence production. These differences are clearly reminiscent of Assal et al.'s (1981) clinical characterization of their patient as "oral Wernicke vs. written Broca."

Given the striking discrepancies in written and spoken production at both the single word and sentence level we decided to examine both areas in greater detail. We first report the results of written and spoken picture naming tasks and then turn to a variety of sentence production tasks.

Spoken and Written Picture Naming

P.B.S. was administered a picture-naming task where he was asked to write and orally produce the names of 51 pictured objects on three different testing sessions. The names of the objects corresponded to one and two syllable words that covered a wide range of frequencies and were 2–6 phonemes and 3–6 graphemes in length.

P.B.S.'s overall written accuracy was 58% (89/153). Of the remaining responses 18% were easily recognizable as the target (NURSE → *nures*), 10% involved semantic errors (COMB → *razor*), and 14% were either unrec-

ognizable or ambiguous nonwords or seemingly unrelated words. In contrast, only 8% (12/153) of P.B.S.'s spoken responses were correct, with errors usually differing considerably from the target (e.g., BOTTLE \rightarrow /kwardz/), although occasionally responses approximated the target more closely (e.g., CARROT \rightarrow /skarlt/). In order to provide an objective measure of the degree of the distortion in spoken and written responses we calculated the proportion of phonemes or graphemes in each target word which were present in the response (regardless of position and without penalty for additional segments). This calculation revealed that for spoken naming on average only 34% of the target phonemes were present in the response, while in written naming an average of 82% of graphemes in the target appeared in the response. Thus, whereas the errors in written production could be considered to typically involve relatively minor deviations from the target, phonemic responses were typically highly aberrant.

In addition, we performed a post-hoc analysis on these data in order to evaluate the influence of frequency and length (in syllables and phonemes) on accuracy (at the whole word and segment level). For written responses a significant effect of length was observed for both whole word ($F(3, 40) = 3.83, p < .02$) and segmental ($F(3, 40) = 5.72, p < .002$) measures of accuracy: PBS performed worse with longer stimuli. No other significant main effects or interactions were observed. For spoken responses no significant main effects or interactions were observed for either frequency or length.

Written and Spoken Sentence Production

Given the scarcity of detailed reports of modality-specific deficits that respect grammatical category and, furthermore, given the relative lack of attention paid to the sentence production performance of these subjects, the focus of our investigation was the examination of P.B.S.'s ability to generate and produce sentences in speech and writing. We report here the results of two analyses of his performance on a number of tasks, the first involves a quantitative assessment of the number of elements from the different grammatical classes that are present in the two output modalities; the second is an attempt to assess the accuracy with which items from the different grammatical categories are produced.

Analysis 1

The purpose of this analysis was to quantify our initial impression that P.B.S.'s written and spoken output contained very different proportions of items from the various grammatical classes, particularly nouns and function words. Because of P.B.S.'s difficulties in written and spoken comprehension, we used tasks that did not require spoken or written input, tasks such as story telling and descriptions of pictures and events. In order to provide a

descriptive summary of his output, we simply counted all the occasions in which nouns, function words, verbs, adjective/adverbs, and non-words appeared in his written and spoken responses. For the purpose of this analysis, the category of function words included articles, pronouns, conjunctions, prepositions, and auxiliaries (when they could clearly be identified as such); the category of verbs included Be and Have when not used as auxiliary verbs; while nouns included both common and proper nouns.

Task 1 (1-4/92). P.B.S. was shown four different sets of 10 pictures (total $n = 40$) and was asked to describe each picture with a sentence in written and oral form. Each set was administered on a different session. For the first two sets he was asked to produce the sentences verbally for the entire set of 10 pictures and then the task was repeated with written responses; for the third and fourth sets, he was asked to orally produce a sentence corresponding to a picture and then to try and write what he had just said. These differences in task administration did not affect his performance so the results from the four sessions are combined.

Task 2 (3/92). P.B.S. was asked to tell the story of Goldilocks and the Three Bears orally and in writing. In scoring the oral responses, adjacent repetitions of single words or phrases were not included (e.g., 'and there's and there's five /wʌd/' is scored simply as 'and there's five /wʌd/').

Task 3 (5/92). P.B.S. was asked to describe with a sentence (written in one session and orally in the following session) 19 actions that were performed by the tester. Actions involved placing two objects in some relationship with one another; for example, a comb was put in a bowl; the tester touched the telephone with a razor; a jar was pushed across the table, etc.

Results. For each of the tasks we counted the instances of recognizable words from various categories (nouns, function words, nonwords, verbs, and adjectives/adverbs) and calculated the proportion of the total utterances that corresponded to each category. The results clearly confirm our initial impression regarding the differences between P.B.S.'s written and spoken production. In all three tasks there is a striking interaction between grammatical category—noun and function word—and the output modality—written or spoken (Table 1). That is, many more function words than nouns were produced in oral description, while in writing many more nouns than function words were observed.

In addition, as mentioned above for spelling of single words, few unrecognizable nonwords were produced in writing. In contrast, P.B.S.'s speech presented with numerous neologisms. As has been noted before in the speech of other individuals producing neologisms, these responses typically seemed to occupy the position of open class vocabulary items (Butterworth, 1979; Lecours, 1982). For example, of the 124 neologisms P.B.S. produced in the spoken picture description task, at least 61 of them were clearly identifiable as occupying noun positions. These were neologisms that followed articles or possessive pronouns and often appeared in prepositional phrases (e.g.,

TABLE 1
The Proportion of Utterances in Different Categories in Three Tasks Involving Written and Spoken Sentence Production

	Nouns/ Total	Funcnt wds/ Total	Nonwords/ Total	Verbs/ Total	Adj-adv/ Total
Picture description					
Written	60% (91/152)	15% (22/152)	8% (12/152)	15% (23/152)	3% (4/152)
Oral	5% (15/325)	53% (172/325)	38% (124/325)	3% (10/325)	1% (4/325)
Story description					
Written	40% (25/62)	22% (14/62)	5% (3/62)	15% (9/62)	18% (11/62)
Oral	4% (10/277)	52% (144/277)	8% (22/277)	18% (51/277)	18% (50/277)
Event description					
Written	52% (39/75)	31% (23/75)	0% (0/75)	16% (12/75)	1% (1/75)
Oral	0% (0/135)	50% (67/135)	38% (51/135)	10% (13/135)	3% (4/135)

into the __, while in the __). Only in story description were relatively few neologisms produced. In this task, however, P.B.S. made extensive use of pronouns (e.g., ‘‘They got one from the mama, they put it here and she said okay, there’s nothing’’ or ‘‘The bad one, he said it’s good and then they got one from the /wʌd/.’’).

The production of verbs (and adjectives–adverbs) was far less discrepant across the two modalities. Verb production, however, was certainly not intact in P.B.S.’s written performance where verbs were often lacking (e.g., *3 bears three beds* or *belt the hand lap*), used in a nonspecific manner such as in the event description task where 8 of the 12 verbs were the verb *turn*, or incorrect (e.g., *boy puddled tire* in response to a picture in which a boy is splashing a tire). In P.B.S.’s speech, however, it was more difficult to determine if, and to what extent, verbs might be underrepresented. Many of the neologisms appeared to occupy verb positions and were sometimes inflected (e.g., in response to a picture of a horse jumping over a fence → ‘‘the /bədzoʊ/ was /ʃɪdlɪŋ/ over the /θʌm/’’), but it was usually difficult to unambiguously classify neologisms as substituting for verbs.

In addition to noting the noun/function word discrepancies in written and spoken production, it was important to determine to what extent the observed proportions corresponded to the performance of unimpaired individuals. In Table 2 we present a comparison of P.B.S.’s written and spoken performance (collapsed across the three tasks) with that of normal subjects on a number of indices reported by Saffran, Berndt, and Schwartz (1989) and Miceli et

TABLE 2

A Comparison of P.B.S.'s Written and Spoken Production Performance (Collapsed across the Three Tasks Presented in Table 1) with That of Normal Speakers

	Closed class/total	Determiner/noun	Noun/pronoun	Noun/verb
Normals	.52-.60	1.00	.80-2.40	1.23 (Miceli et al.) 2.36 (Saffran et al.)
P.B.S. written	.20 (59/289)	.1 (16/155)	155 (155/1)	3.5 (155/44)
P.B.S. oral	.52 (383/737)	4.9 (123/25)	.20 (25/123)	.3 (25/74)

Note. Indices of normal production are from Saffran, Berndt, and Schwartz (1986) and Miceli et al. (1984).

al. (1984).⁴ It is particularly informative that P.B.S.'s production of function words in speech is within the normal range since this is one important indication that it is not the case that P.B.S. is simply producing unstructured utterances containing randomly placed function words, but rather that his use of the closed class vocabulary resembles that observed in the grammatical utterances produced by unimpaired individuals. In contrast, P.B.S.'s use of function words in writing is clearly abnormal.

The discrepancy in noun use in the two modalities is readily apparent in the indices comparing subcategories of function words with nouns. Thus although nouns and determiners were produced in a 1:1 ratio in normal subjects, P.B.S.'s spoken output reflects the much higher than normal ratio of 5:1, while in his written production only one determiner was produced for every ten nouns. Likewise the ratio of nouns to pronouns, although quite variable in normal speakers, was clearly abnormal for P.B.S.—155:1 in writing and 1:5 in speech.

Finally, the comparison of nouns and verbs is consistent with our earlier observation that, although verb use is not normal in either modality, it is less affected than are spoken nouns or written function words.

In summary, this analysis provides clear evidence that in speaking P.B.S. is able to produce a seemingly "normal" distribution of function words, while his production of these items is severely reduced in writing. Nouns, on the other hand, are plentiful in his writing but are rarely produced in speech. Of additional interest is the fact that neologisms occupy many noun positions and at least some verb positions in spoken production.

Analysis 2

In describing P.B.S.'s impairments in written and spoken production as being complementary, we have implied not only quantitative differences

⁴ The data from the normal subjects was obtained by Saffran et al. from samples of spontaneous speech and picture description in English, while Miceli et al. report from spontaneous speech in Italian.

across the two modalities but also: (1) that P.B.S. could produce relatively normal sentence structure in speech, but not in writing and (2) that P.B.S.'s written output consisted primarily of the nouns that were not present, or at least not recognizable, in his speech. We have argued for the former on the basis of the apparently normal distribution of function words in speech and their abnormal reduction in his writing (Table 2). For the latter we have not yet presented any evidence. With this second analysis we hope to provide further support for both of these points.

Thus, with respect to his spoken responses, although Analysis 1 already provided considerable support for the claim that P.B.S.'s speech did not consist simply of the haphazard production of function words and neologisms, an assessment of the syntactic and semantic appropriateness of his spoken responses would constitute further relevant information. With respect to the claim regarding the semantic appropriateness of the nouns produced in P.B.S.'s writing, we need to establish that the nouns which were produced actually corresponded to the pictures or events he was trying to describe. Similarly, it would also be useful to evaluate the extent to which even the reduced written function word vocabulary was syntactically appropriate.

In order to make these determinations we took P.B.S.'s written responses and assigned to each one a potential target utterance and then compared the extent to which his actual responses matched the targets. P.B.S.'s written and spoken responses in the picture description task (Task 1) were used for this analysis. This particular task was selected as it offered more constraints than the other two in determining potential target sentences. For example, when, in response to the picture of a horse jumping over a fence, P.B.S. wrote *horse mangers fence*; the intended response was determined to be *The/A horse jumps the/a fence*. In such a case the two nouns he produced were considered to be correct, the two articles were scored as omitted (in addition, the verb stem (*manger*) was incorrect and the verb inflection (*s*) was correct—for these data see Appendix A, Table A). This procedure is clearly not unproblematic, especially with respect to the function word vocabulary and morphology. Thus, although it would be hard to argue that the target utterance didn't appropriately include horse and fence, it is entirely possible that P.B.S. intended to write *A horse is jumping over a fence* or *The vigorous stallion exuberantly cleared the formidable obstacle*, or an indefinite number of variations. We always assigned the least complex structure possible while trying to accommodate all of the words and morphology actually produced. Although this measure may underestimate the words that might have been deleted from the intended utterance, it should at least allow us to evaluate the extent to which the words actually produced were appropriate for a description of the pictured event. Target sentences could be generated for all but three of P.B.S.'s written responses in the picture description task.

The scoring of P.B.S.'s spoken responses was far more problematic than the scoring of his writing, given the paucity of content words and the many

TABLE 3

Analysis of P.B.S.'s Performance with Nouns and Function Words in the *written* Picture Description Task

	Noun positions	Function word positions
Total number in the target sentences	$n = 84$	$n = 117$
Total number actually produced	$n = 84$	$n = 16$
Proportion omitted	0%	86% (101/117)
Correct/total produced	98% (82/84)	88% (14/16)
Unrecognizable nonwords/total produced	0%	0%
Within category substitutions/total produced	2% (2/84)	12% (2/14)

false starts and mid-sentence changes. Fortunately these difficulties did not affect all items; for example, in response to a picture of a man and woman sleeping in a bed, P.B.S. said: "the /bold/ and the girls /æz/ to /wæz/," which was interpreted as "the boy and the girl went to bed (or sleep)." Clearly this is not the only possible interpretation of his response but it allows us to have at least a rough estimate of the extent to which P.B.S.'s spoken production is interpretable and potentially appropriate to a given context. For his spoken responses only 22/40 sentences contained sufficient unambiguous material to permit the assignment of a reasonable target utterance. Many of the problematic responses contained so many neologisms that insufficient constraints on possible sentences were available. For example, the picture of a boat tied to the roof of a car led to the response "the /wud/ /a/ /rAdtAv/ /wAzld/ to the /rAd/. Although this response might have corresponded to a target such as "the boat was tied to the roof (or car)" the actual response provided too little information to propose such a target with any confidence. Thus the fact that target sentences were not generated for many of P.B.S.'s spoken responses does not imply that these responses were ungrammatical or inappropriate, just that they offered too few clues regarding the identity of the intended utterance (see Appendix B for examples of P.B.S.'s spoken and written responses in this task).

Results. In Table 3 we compare the number of noun and function word positions that were present in the written *target sentences* with the number of items in these categories in P.B.S.'s *actual responses*. This is followed by an assessment of the accuracy or appropriateness of his responses as determined by the degree of match between responses and targets. To understand the table it may be helpful to consider as an example his response to a picture of a boy eating an apple. P.B.S. wrote: *boy bitten apples*. The potential target sentence that we generated was: *The/A boy has bitten an/the apple*. Note that the *target* sentence has two nouns and three function words. This results in an omission rate of 0% for nouns and 100% for function words because

TABLE 4

Analysis of P.B.S.'s Performance with Nouns and Function Words in the *spoken* Picture Description Task

	Noun positions	Function word positions
Total number in the target sentences	$n = 49$	$n = 90$
Total number actually produced	$n = 49$	$n = 88$
Proportion omitted	0%	2% (2/90)
Correct/total produced	24% (12/49)	76% (67/88)
Unrecognizable nonwords/total produced	71% (35/49)	5% (4/88)
Within category substitutions/total produced	4% (2/49)	19% (17/88)

only the two nouns were actually produced. Both of the nouns produced were correct, or at least appropriate for describing the picture; note also that no nouns considered essential for the description of the picture were omitted. Combining the data generated in this manner for all the written responses we can see: (1) practically all of the nouns that were produced were appropriate for describing the pictures and no essential nouns were omitted (the three within-category errors were close semantic errors: GRASS \rightarrow *leaves*, FACE \rightarrow *head*, SHIRT \rightarrow *skirt*); and (2) function words were almost entirely absent, although most of those that were produced could be used in generating target sentences (e.g., the picture of a man repairing a car \rightarrow *men was meched the car*, which was assigned the target sentence: *the man was repairing the car*.) These results, therefore, support the claim that P.B.S.'s writing contains almost all of the nouns and few of the function words required for accurate picture description.

Regarding P.B.S.'s speech, Table 4 indicates that when his spoken responses were used to generate target sentences these included 90 function word positions and 49 noun positions. Ninety-eight percent of these function word positions were actually filled and 100% of the noun positions contained phonological material. However, of the responses that occupied noun positions only 20% were correct or recognizable, while 76% involved neologistic responses.⁵ In contrast, 76% of the function word positions were filled with syntactically appropriate words, only 5% of the target function word positions contained neologistic material, and 19% contained other function words

⁵ We find, as did Buckingham, Whitaker, and Whitaker (1975) that nouns are somewhat more likely to be correct when they occur as the subject of a sentence rather than as the predicate. The interpretation of this finding is somewhat problematic, however, because first, subject/predicate status is confounded with sentence position—subject nouns systematically occur earlier in the sentence than the predicate nouns. Second, the only nouns that were correctly produced as subjects were "girl" and "boy." In the target sentences that were used, these words only occurred in subject position making it impossible to determine if this was merely an item-specific effect.

that did not correspond to those in the target sentences (e.g., a picture of a man washing a car → “the /wʌd/ are /rʌzd/ the /ruʒ/.” The auxiliary *are* is inappropriate and should be *has* or *is*—“The man has/is washed/washing the car”).

The results regarding noun positions in spoken output are relatively straightforward: although few recognizable nouns were produced, most of the nouns positions were filled, albeit with neologistic utterances. These are just those positions which were produced accurately in P.B.S.’s written responses. Thus, the complementarity of noun production in the two modalities is quite apparent.

Because of the limitations in the scoring methodology, the results regarding the spoken function words are more problematic in their interpretation. Thus, the method used to generate target sentences favors finding a high proportion of syntactically appropriate function words simply because it uses the function words that are produced to provide constraints on possible target sentences. Therefore one might be concerned that the 76% accuracy reported in Table 4 may overestimate P.B.S.’s actual ability to produce spoken sentences with appropriate syntactic structure. On the other hand, some of the 19% errors that are reported may have resulted from our generating the wrong target sentences or from mid-sentence changes in structure prompted by the difficulties P.B.S. encountered in filling positions. In spite of these difficulties what is quite remarkable is the fact that, in speech, 95% of the potential function word positions were filled with clearly identifiable function words while in writing *no sentence was ever produced in which all function word positions were filled*.

Localization of the Spoken Deficit

These analyses of P.B.S.’s written and spoken responses in sentence production tasks document a case of differential production of nouns and function words in spoken vs. written output. We can now turn to the question of how best to characterize the damage to the underlying functional architecture that might be responsible for this pattern of performance. We will first consider the deficit/s affecting spoken output and then turn to P.B.S.’s written production.

Regarding P.B.S.’s spoken production, the question concerns the origin of the striking differences in function word vs. noun production. Within the sentence production framework we have outlined (Fig. 1) the presence both of an adequate function word vocabulary and appropriately placed noun positions in P.B.S.’s speech indicates that the processing and representational stages involved through the level of generating a phrasal planning frame are relatively intact (at least with respect to these grammatical categories). This leaves three possibilities: (a) the dissociation between categories results from the relative preservation and damage to the category-specific lexical phono-

TABLE 5
Accuracy of P.B.S.'s Spoken Responses in
Picture Description for Nouns and Function Words
× Phoneme Length

No. of phonemes	Function words	Nouns
Two	82%	56%
Three	68%	22%
Four to six	60%	0%

logical forms themselves (or to separate procedures responsible for their retrieval of forms corresponding to these grammatical categories), (b) the pattern results from the fact that function words are far more frequent than nouns and thus benefit from the protection that frequency provides against the effects of neurological insult (see Ellis et al., 1983) and/or (c) the differences arise from the fact that function words are generally shorter than nouns.

Our earlier analysis of P.B.S.'s picture naming performance involving the single word production of *nouns* revealed no significant effects of length or frequency. However, the sentence production tasks administered to P.B.S. allow us to directly compare function words and nouns in terms of the effect of length on performance. In order to do so we used the target sentences generated in Analysis 2 to establish a set of nouns and function words that we assumed that P.B.S. intended to produce. We then considered the effect of length and grammatical category on accuracy (Table 5). An analysis of variance revealed significant effects of grammatical category ($F(1, 119) = 6.82, p < .01$) and length ($F(3, 119) = 12.04, p < .0001$) with no significant interactions. In contrast to the previous results here we observe an effect of length in spoken production. However, the analysis also clearly reveals differences between noun and function word production that are apparent at every length and, therefore, are not reducible to effects of length.

Having established that function words are not selectively preserved because of their shorter length we can turn to the issue of word frequency. Unfortunately frequency and grammatical category are completely confounded in this data set such that the frequency range of the function words is non-overlapping with the frequency range of the nouns making it impossible to disentangle the two effects. As a consequence we can conclude that the differential production of nouns and function words in spoken output reflects either grammatical category and/or frequency differences.

As indicated in the Introduction, to the extent to which one can establish a lexical level locus for the spoken deficit, the hypothesis of orthographic autonomy is supported by cases in which neologistic spoken production is accompanied by relatively spared written output. There are a number of reasons that indicate a lexical level locus of P.B.S.'s pattern of spoken produc-

tion. First, P.B.S. does not exhibit the articulatory difficulties that would be indicative of a peripheral deficit. Second, the fact that the grammatical category and/or frequency effects are not reducible to length effects constitutes positive evidence of a lexical level deficit. Finally, the absence of consistent length effects in the naming of objects stands in marked contrast with the striking effects of syllabic length exhibited by other subjects whose deficits have been attributed to a post-lexical locus (Pate et al., 1987, Caplan, 1987).

The Localization of the Written Deficit

The localization of the deficit responsible for P.B.S.'s pattern of written production in which nouns are spared relative to function words is considerably more straightforward. The analysis of P.B.S.'s spelling errors in written picture naming revealed effects of length that are indicative of a post-lexical graphemic buffer impairment (see Caramazza, Miceli, Villa, & Romani (1987) for a discussion of the pattern of performance expected to result from damage to the graphemic buffer). However, the dissociation between function word and noun production certainly cannot be attributable either to effects of length and/or frequency since these factors would predict the opposite dissociation from what was observed. We are left, therefore, with the following alternatives: (a) that the noun/function word effect arises either as a result of damage to modality-specific grammatical category representations/processes or (b) from damage to higher level syntactic/semantic ones.

Critical evidence in adjudicating between these alternative accounts is the fact that function words were produced in a relatively normal manner in speech. This indicates that the prior, presumably amodal, syntactic/semantic processes involved in generating function word positions must have been relatively intact. That is, regardless of whether function words were spared in speech because of their grammatical category membership or their frequency, their relatively normal distribution attests to the integrity of prior processing. The evidence, therefore, indicates a deficit affecting representations/processes that are not only dedicated to the function word vocabulary but are *specific to the written modality*.

In sum, this set of results poses a challenge to the phonological mediation hypothesis of lexical production and are entirely consistent with the hypothesis of orthographic autonomy. Thus this case converges with the observations mentioned in the Introduction in support of a functional architecture of the lexical system in which the retrieval of orthographic and phonological forms can occur independently. Furthermore, the case provides additional evidence of the modality-specific organization or representation of grammatical categories. In terms of our understanding of brain-cognition relationships, these findings indicate that the neural substrate supporting sentence production has sufficient internal organization that information that is specific both to

modality and grammatical category can be selectively affected by neurological damage.⁶

In the Discussion we will consider certain clarifications, implications, and potential alternative accounts of the performance pattern exhibited by P.B.S.

DISCUSSION

Sentence production theorists have generally been silent with respect to the manner in which the orthographic forms of lexical items are generated in written sentence production. The complementary patterns of written and spoken production exhibited by P.B.S.—difficulty with nouns vs. function words in spoken output and the reverse pattern in written output—provide us with significant insight into the nature of written sentence production. Specifically these observations: (a) support the view that the retrieval of orthographic material to fulfill the syntactic/semantic requirements of a sentence plan can occur independently of comparable phonological processes and (b) the evidence indicates that processes and/or representations that are specific to orthographic form are sensitive to grammatical category distinctions.

Is Orthographic Autonomy Necessarily the Case?

The evidence from P.B.S.'s performance, as well as the evidence cited in the Introduction, indicates that the lexical system is organized in such a manner that damage affecting phonological representations need not affect the availability of corresponding orthographic ones. However, the fact that orthographic representations may be recovered without a mediating role from phonology does not, of course, preclude the possibility that phonological mediation via a direct lexical phonology–orthography link may not be an additional option. Clear evidence on this point is not available. This is due to the fact that once the option of orthographic autonomy has been established, an architecture is created in which it is possible to go either directly from semantics to orthography or to go from phonology through semantics to orthography (see Fig. 3). It is then difficult to gather empirical evidence that distinguishes this arrangement from an architecture that additionally

⁶ We have focused this investigation specifically on sentence production and have not made reference to category and modality differences in single word processing. Although results obtained with P.B.S. regarding single word production are consistent with those obtained in sentence production, the tasks employed to examine performance—reading and writing to dictation—require the use of input processes which we know have been affected in this patient. Thus, any grammatical category effects observed in these tasks could have either an input and/or output locus. Although for these reasons we have not addressed issues of single word processing with P.B.S., we assume that the lexical retrieval mechanisms engaged in sentence production are just those employed in single word production.

allows for a direct connection (without the mediating role of semantics) between phonology and orthography.

What Is Meant by Redundant, Modality-Specific Grammatical Category Distinctions?

It is generally accepted that grammatical category distinctions must be present at the level of amodal semantic/syntactic stages such as (in the Garrett framework) those involved up to (and including) the development of the surface phrasal geometry (see Fig. 1). However, it is not obvious that such distinctions should also be present at subsequent modality-specific stages. Nonetheless, as mentioned earlier, evidence from normal speech errors has led investigators such as Garrett (1984) to propose distinct procedures responsible for specification of the phonological forms of content vs. function words. What has not been considered before is whether such distinctions also extend to orthographic forms. The evidence that we have presented here indicates that it does.⁷ Thus, both the pattern of performance exhibited by P.B.S. and other similar cases, as well as the modality-specific noun/verb dissociations described in the Introduction, indicate that the specification of *both* orthographic and phonological form is organized/represented/processed in such a manner that brain damage can result in the selective damage and preservation of forms corresponding to different grammatical classes.

It is important to be clear, however, that we are not making any specific claims regarding whether the modality-specific representation of grammatical category information is present at the level of modality-specific procedures responsible for making the forms available or at the level of the modality-specific forms themselves (see Fig. 5). The claim is simply that grammatical category distinctions are present at modality-specific levels. As such the claim can be considered to be an extension to the orthography of the existing claim (based on patterns of normal speech errors) regarding grammatical category distinctions at the level of assignment of lexical phonological form. This interpretation of the modality specific noun/verb and noun/function word effects within a sentence processing framework is schematically summarized in Fig. 6.

In this context it is interesting to note that Bub and Kertesz (1982), in their discussion of a subject with a pattern of performance similar in many respects to that of PBS, argue that the orthographic forms themselves for function words were intact. The basis for the claim is that their subject was able to accurately write function words to dictation. The observation is interesting and may indeed indicate the integrity of the lexical orthographic forms. Alternatively, however, in writing to dictation there is the possibility

⁷ Interestingly, although normal written errors have not received the empirical attention that spoken errors have, Hotopf (1980) noted a differential rate of omission errors for content vs. function words in both the writing and the speech of normal subjects.

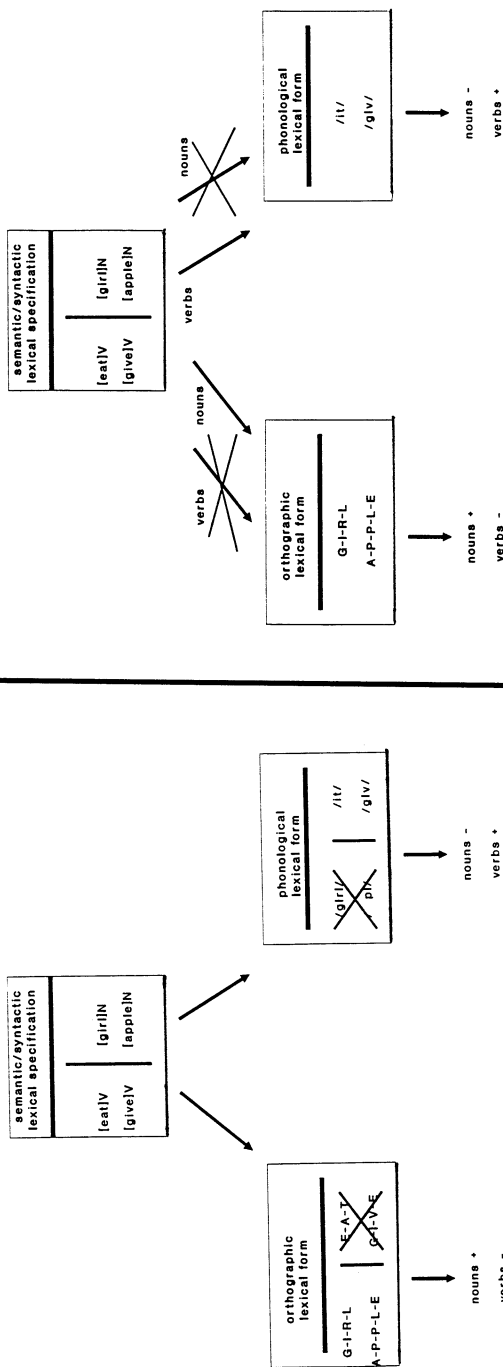


FIG. 5. Modality-specific grammatical category distinctions at the level of (a) the forms themselves or (b) at the level of procedures responsible for their specification.

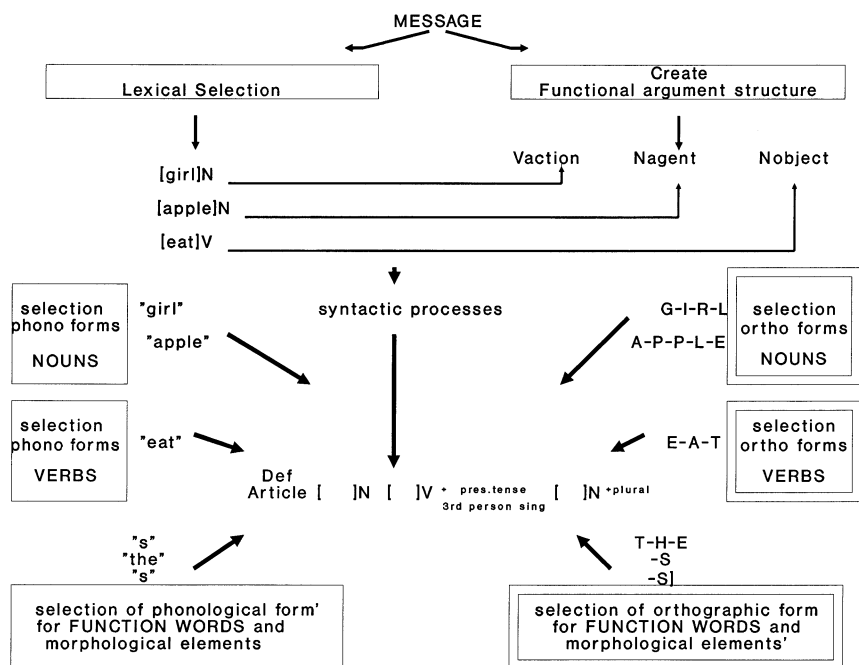


FIG. 6. A schematic depiction of the place of modality specific representation of grammatical categories in the course of sentence production.

that sublexical information may be computed and serve to supplement inadequacies in the stored lexical representations. Although the Bub and Kertesz patient was not very successful in sublexical phonology-to-orthography conversion (as evidenced by her poor pseudoword spelling), several of the phonemes of each pseudo-word stimulus were usually successfully converted (e.g., "hafe" → HAFT, "brod" → BARD). This sublexically generated information, if combined with partial lexical information may account for her good performance in writing to dictation (see Hillis & Caramazza, 1991, for a discussion of the summation of partial information from lexical and sublexical sources). For these reasons we reserve judgement regarding whether the locus of the grammatical category distinctions lies at the level of the modality-specific representations or within the modality-specific processes responsible for their retrieval. In fact we have argued (Rapp & Caramazza, 1993a) that distinctions such as access/storage, representation/process may not even be empirically distinguishable within certain architectural types.

Potential Alternative Accounts

Syntactic/semantic processes specific to written sentence production. An alternative account to the one we have proposed is one in which there is an entirely different sentence production system for written communication,

sharing none of the semantic/syntactic components of the speech production system beyond the message level. Although we are unaware that anyone has advanced such a proposal, it is certainly a logical possibility and we will mention at least for the sake of completeness.⁸ Such an architecture would allow one to attribute the observed grammatical category distinctions to a level of specifically orthographic syntactic/semantic representations and processes and would, therefore, do away with grammatical category specification at the level of form. However, although the data provided by P.B.S.'s performance can easily be accounted for within such a proposal, it requires an amount of redundancy that should be posited only when data cannot be accommodated within other more parsimonious approaches.

Resource/capacity limitation accounts. There are a variety of capacity or resource limitation accounts that one might consider in attempting to interpret P.B.S.'s pattern of written sentence production. What these accounts have in common is the view that the reduction in P.B.S.'s written function word vocabulary is a strategic response in the face of resource or capacity limitations. We will argue that none of these accounts are entirely satisfactory.

For example, one might argue that function words are largely deleted in P.B.S.'s writing simply because writing is an effortful and difficult procedure and that, given this situation, P.B.S. has attempted to communicate only the most essential information—nouns. Under such a scenario central syntactic processing is intact and the grammatical category effects are considered to be a strategic response to a peripheral deficit—one affecting the motoric aspects of writing. The problem with such an argument is that P.B.S.'s writing was not effortful in the least. He wrote easily with his left hand which was the hand he used pre-morbidly (Fig. 7 provides a characteristic sample of his cursive and printed responses).

A closely related hypothesis considers the reduction in function word vocabulary as a response to the non-motoric, yet post-lexical, graphemic buffer difficulties that apparently affected P.B.S.'s written performance. Again one might speculate that difficulties at such a level could prompt the deletion of function words. There are several reasons why this is unlikely. First, our experience with various other subjects with writing impairments limited to the level of the graphemic buffer provides no indication of a telegraphic style of written sentence production. Second, P.B.S. had difficulties with written function word vocabulary even in sentences where there was no evidence of spelling difficulties. Furthermore, P.B.S.'s difficulties in producing nouns

⁸ However, such a proposal bears a relationship to the particular version of the modality-specific semantics hypothesis that suggests that different semantic representations exist for items according to the modality in which the information about the item was acquired (see Caramazza, Hillis, Rapp, & Romani, 1990). Furthermore Shallice (1993), in his discussion of modality specific semantics, proposes that sections of a lexical network will develop tighter interconnections by virtue of the frequency with which particular input-meaning-output connections are activated (but see Rapp, Hillis, & Caramazza, 1993b).

Dog reaching boxes.

Boy & Boy penish wrote paper.

HORSE MANGERS FENCE.

Boy WASHED CAR.

Boy HIGH Aps.

GRAMDA LUNCHEID KID.

FIG. 7. Representative samples of P.B.S.'s cursive and printed handwriting obtained from the picture description task.

were far more severe in spoken than written production and yet function words were relatively spared in spoken production.

Another subtler version of this hypothesis has been suggested (see Kolk & Heeschen, 1992), whereby the omission of function words (in speech) occurs as a strategic response to a reduction in "capacity" at syntactic levels of representation. These authors, argue that if there is insufficient capacity for a complete sentence because, for example, syntactic structures are decaying rapidly, then a sentence fragment may be produced. Although potentially interesting, it is unclear exactly what might be meant by such a capacity limitation. Furthermore, the problem for this hypothesis in the case of P.B.S. is that the hypothesized diminution in capacity at the syntactic level affects written production in one way while speech is affected in a complementary manner. In addition, PBS exhibited a noun/function word effect even when he had only to produce a single word—in a cloze task which involved filling in one missing word in a sentence (paired with a picture), P.B.S. was 100% correct in supplying missing nouns and 0% correct with missing function word.⁹

Finally there is a closely related possibility raised by Bub and Kertesz

⁹ Differences in patterns of omission vs. substitution of closed class items have also been attributed to differences among tasks such as story telling, picture description, answering questions, etc. (e.g., Martin, Wetzel, Blossom-Stach, & Feher, 1989). In the case of P.B.S., however, the differences in spoken and written production occur *on the same tasks*.

(1982) that intact phonological processing is required to maintain a syntactic construction throughout the production process. On this basis they suggest that the observed pattern of difficulties in writing may result from a limitation in storage capacity related to the subject's phonological deficit. This proposal, as the previous one, is problematic because it is not clear why, in the face of such a storage limitation, phonological production should be affected so differently from orthographic production. Furthermore, there are cases such as the one reported by Levine, Calvanio, and Popovics (1982) where an individual who is unable either to speak, experience inner speech or appreciate the phonological structure of words, is nonetheless capable of accurately producing syntactically complex sentences and paragraphs in spontaneous writing. Such evidence would seem to indicate that intact phonology is not required for the written production of phrases and sentences.

Right-hemisphere hypothesis (RHH). Certain researchers (e.g., Coltheart, 1980; Coslett & Monsul, 1994; Coslett & Saffran, 1989; Shallice & Saffran, 1986; Schweiger, Zaidel, Field, & Dobkin, 1989; Zaidel & Schweiger, 1984) assume that what we observe after damage to the left hemisphere is the functioning of an intact right hemisphere that contains a number of representational/processing systems that are somewhat redundant with those of the left hemisphere. These researchers have argued that this situation is problematic for those who use brain-damaged performance to develop theories of normal cognition because these right-hemisphere processes are not normally used. These redundant, right-hemisphere systems are, presumably, back-up systems which are activated (or released from inhibition) in the face of left-hemisphere damage. The proposal, which originated from work with hemispherectomy and commissurotomy patients, has been used to account for a wide range of performance patterns in individuals with brain damage affecting the left hemisphere. For example, Coslett and Saffran (1989) have proposed that the normal right hemisphere duplicates (albeit in a somewhat impoverished manner and to an extent which may vary from individual to individual) all of the systems that have been posited for the left-hemisphere processing of pictures and written materials except for a phonological system. That is, they assume that the right hemisphere has back-up systems for computing object constancy, structural representations of objects, an orthographic lexicon and a semantic system.

This type of proposal is still invoked despite numerous reviews of the topic that have found that there is little support for the position (we refer the reader to a thorough recent discussion in Baynes, 1990, and see also to Gazzaniga, 1983; Millar & Whitaker, 1983; and Patterson & Besner, 1984). Because of the persistence of such accounts and because P.B.S.'s performance exhibits certain features that RH proponents consider to be markers of RH involvement—a bias toward content words and impoverished spoken language—we will consider a RH based interpretation of P.B.S.'s performance pattern.

A RH interpretation of this case attributes P.B.S.'s pattern of written responding to characteristics of intact RH structures, while the pattern of spoken responding reflects the functioning of the damaged left hemisphere. Under such a hypothesis P.B.S. writes with his right hemisphere and speaks with his left. How does such a state of affairs arise? Presumably brain damage has affected the left-hemisphere phonological and orthographic lexicons. Speech, has no choice but to rely on the damaged left hemisphere; writing, on the other hand, can take advantage of the redundant right-hemisphere functions. In order to arrive at such an interpretation the following assumptions are required.

First, the RHH requires that we assume that the right hemisphere has a set of back-up systems that are not normally used and that await brain damage in order to be activated. Second, and independently of questions regarding the basis for the first assumption, there is the further assumption that in spite of the right-hemisphere's apparently considerable capacity for duplication (at least an orthographic lexicon and lexical semantic system), it has not developed a back-up phonological lexicon. The motivation for this particular lapse is not developed. Third, in contrast to the corresponding left-hemisphere structures, the intact RH semantic and orthographic systems are curiously limited in that they include representations only (or primarily) of concrete content words. Fourth, in the case of P.B.S., not only would one have to assume that both left-hemisphere orthographic and phonological lexicons were severely affected, but that the LH orthographic lexicon was so badly affected that even the very highest frequency items such as function words were unavailable. Otherwise, for written production the LH orthographic lexicon could provide the high frequency function word vocabulary and the RH the lower frequency content word vocabulary.

In addition to assessing the plausibility of this set of assumptions, there are a number of other considerations involved in evaluating a RHH interpretation of this case. It is important to note that the cost incurred by adopting this set of largely unmotivated assumptions is *added* to the assumptions of the non-redundant architectures; these are required to account for cases in which RH mechanisms are not invoked. This considerable expenditure of theoretical capital on basic assumptions does not buy protection from, in fact perhaps even promotes, contrived distinctions. For example, within the context of the modality-specific grammatical class issue, the RHH would provide one type of explanation for the noun/function word effects observed in P.B.S.'s writing and another for the noun/verb dissociations described in the writing of other subjects that we have referred to. Thus, while the noun/function word differences would be thought to reflect RH characteristics, the noun/verb effects are not interpretable as RH effects since this dissociation occurs *within* the class of content words and affects both abstract and concrete nouns and verbs (Caramazza & Hillis, 1991; Hillis & Caramazza, in

press). These modality-specific noun/verb differences must, presumably, be accounted for in terms of the characteristics of left-hemisphere structures that represent differences between nouns and verbs in writing and speech. In contrast to this arbitrariness, within a nonredundant architecture we provide similar accounts for both noun/verb and noun/function word effects.

Finally the most serious difficulty with the RHH interpretation of the modality specific grammatical category effects is that it is not clear that there is any evidence that would contradict the view. This arises from the fact that any observed effect can be attributed to either left or right hemisphere mechanisms or some combination thereof. This fundamental problem is well-stated by Baynes (1990) who writes "such an explanation is unpalatable as it appears to be untestable; once such an idea is accepted, any pattern of skills can be explained in terms of right hemisphere mediation" (p. 175).

Implications for the Interpretation of Sentence Production Deficits

One of most striking aspects of this case is the fact that the superior performance with nouns vs. function words (observed in P.B.S.'s writing) is restricted to the written modality. Individuals are commonly reported with apparently similar difficulties affecting the closed class vocabulary, but these are typically in spoken output and generally presumed to occur (and occasionally documented to do so, see Caramazza & Hillis, 1989) in the written modality as well. Thus, difficulty in producing elements of the closed class vocabulary has often been attributed to a deficit affecting the syntactic processes (Berndt & Caramazza, 1980; Saffran, Schwartz, & Marin, 1980; Zurif, Caramazza, & Myerson, 1972) required to develop a sentence frame. However, on the basis of P.B.S.'s spoken production, we have argued that the abstract, modality-independent syntactic processes required to generate the structures underlying P.B.S.'s speech (and presumably his writing) must have been relatively spared from damage. It is precisely this conclusion that allows us to attribute the grammatical category effects observed in his writing to a modality-specific deficit downstream from the syntactic processes.

This finding indicates that, at least in some cases, the deficit responsible for a paucity of function word vocabulary may arise at the level of modality-specific representations. It does not, however, indicate that damage to syntactic representations/processes may not *also* result in performance patterns similar to those observed here. In cases involving amodal semantic/syntactic level deficits, and barring additional deficits, impaired function word production should be apparent in both written and spoken modalities. Thus the information provided by a careful assessment of written sentence production in individuals with impaired spoken sentence production may provide powerful constraints on the interpretation of the underlying deficit.

SUMMARY

In conclusion, the striking modality-specific grammatical category difficulties exhibited by PBS can be understood if we assume a cognitive architecture for sentence production that is internally complex and organized in a manner that allows for considerable independence in the representation and processing of the orthographic and phonological forms of items of different grammatical categories. This detailed description of the structure of the cognitive systems involved in language production is useful, not only in permitting a more in-depth understanding of the deficits exhibited by neurologically impaired individuals but, also because it provides further constraints upon our theories of how the brain accomplishes the task of producing language.

APPENDIX A

Table A: Accuracy of P.B.S.'s Spoken Production When Compared to Target Utterances for Various Grammatical Categories

	Noun- stem	FW- article	FW- auxiliary	FW- prepositn	FW- conjunct	FW- pronoun	Verb- stem	Inflectn- noun	Inflectn- verb
correct	24% (12/49)	92% (35/38)	38% (5/13)	65% (11/17)	100% (8/8)	50% (8/16)	13% (3/23)	76% (37/49)	61% (14/23)
deletion	0	0	15% (2/13)	0	0	0	4% (1/23)	0	30% (7/23)
neologsm	71% (35/49)	5% (2/38)	8% (1/13)	0	0	6% (1/16)	74% (17/23)	—	—
subst	4% (2/49)	0	38% (5/13)	29% (5/17)	0	44% (7/16)	9% (2/23)	24% (12/49)	9% (2/23)
insertion	0	3% (1/38)	0	6% (1/17)	0	0	0	0	0

Note. Note that results for inflections include as correct those cases where no overt inflection is expected and none actually appears (e.g., for dog (singular) the response “dog” was considered to be correct on the inflection. Note also that there is considerably ambiguity in scoring the inflections and that the absence of the appropriate phonology for an inflection was interpreted as a deletion, although if the stem was neologistic it is possible that the inflection was also neologistic rather than deleted (e.g., for fence the response /θΛ/ was scored as neologism for the stem and correct for the inflection but it is conceivable that the final phoneme was actually a neologistic inflection.

Table B: Accuracy of P.B.S.'s Written Production When Compared to Target Utterances for Various Grammatical Categories

	Noun- stem	FW- article	FW- auxiliary	FW- prepositn	FW- conjunct	Verb- stem	Inflection- noun	Inflection- verb
correct	96% (81/84)	3% (2/75)	26% (5/19)	25% (4/16)	43% (3/7)	31% (11/36)	82% (69/84)	64% (23/36)
deletion	0	96% (72/75)	68% (13/19)	75% (12/16)	57% (4/7)	14% (5/36)	4% (3/84)	22% (8/36)
neolgsn	0	0	0	0	0	33% (12/36)	0	0
subst	4% (3/84)	1% (1/75)	5% (1/19)	0	0	22% (8/36)	14% (12/84)	14% (5/36)
insertion	0	0	0	0	0	0	0	0

Note. Note that results for inflections include as correct those cases where no overt inflection is expected and none actually appears (e.g., for dog (singular) the response “DOG” was considered to be correct on the inflection).

APPENDIX B

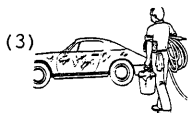
Examples of P.B.S.'s spoken and written responses in picture description



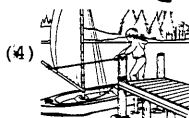
- (1) WOMEN PLAYING AERPLACE
a /lAv/ /wadzətIv/ the /dAm/ for him



- (2) MAN PLAYING DEER
a /wAz/ was /šrAm/ them /lAs/



- (3) BOY WASHED CAR
the /wAd/ are /rAzd/ the /rudz/ with /lAd/ and /tAv/
in a /rədId/



- (4) BOY YASHT SEA
the boys /wAd/.../rAd/ into the /wAd/



- (5) GIRL AND BOY TELLERS
the boys and the /lAv/ /rəsi/ the /wAd/



- (6) HORSE MANGERS FENCE
the /bədzoʒ/ was /šidIŋ/ over the /θAm/



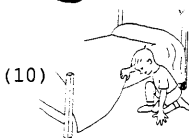
- (7) BOY ROPEING ALPS
the /boIdz/ /wədozd/ /əbAnd/ on the /lAd/ /sAv/



- (8) BOY AND GIRL TOO BED
the /boId/ and the girls /æz/ to /waz/



- (9) BOY AND BOY AND GIRL VIEWED TELEVISION
the boys and a /lAv/ /wAd/, /wAd/ /tAnz/



- (10) BOY BANKANT COVERS
the /lAdləs/ and the, and the, the something over /Iθ/
now

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