

The Independence of Phonological and Orthographic Lexical Forms: Evidence from Aphasia

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WMA suffers from damage to the semantic component of the lexical semantic system and from damage to sublexical phonology–orthography and orthography–phonology conversion procedures. His performance on picture naming tasks that require two consecutive responses was used to explore issues concerning the relations between the phonological and orthographic components of the lexical system. Responses to tasks requiring responses in different modalities (one oral and one written) often resulted in lexically “inconsistent” responses. For example, to a picture representing pliers, WMA said “pincers,” but wrote *saw*; and, to a picture representing peppers, he wrote *tomato* but said “artichoke.” By contrast, inconsistent responses never occurred in tasks that required two consecutive responses in the same modality (oral or written). In these tasks, WMA always produced the same (correct or incorrect) word twice. These results rule out the hypothesis that phonological mediation is necessary for writing, and suggest instead that orthographic word forms are autonomous from

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phonological forms, and that they are activated directly from lexical semantic information. However, the results do not allow us to distinguish between a weak version of the orthographic autonomy hypothesis—that there are direct connections between phonological and orthographic forms, which are impaired in WMA—and a strong version of the same hypothesis—that phonological and orthographic word forms are completely autonomous but that the selection of a word form for output in a given modality can be constrained by sublexical conversion mechanisms, which are impaired in WMA.

INTRODUCTION

There is widespread agreement in the psycholinguistic and cognitive neuropsychological literatures on some of the major aspects of the structure of the lexical system. Most models of lexical processing assume some type of network structure and distinguish between two main levels of processing—the lexical semantic (or lemma) and lexical form (or lexeme) levels (e.g. Bock & Levelt, 1994; Caramazza & Hillis, 1990; Dell & O'Seaghdha, 1992; Garrett, 1980; Kempen & Huijbers, 1983; Levelt, 1989; but see Seidenberg & McClelland, 1989, for a proposal in which lexical entries are not discretely represented). The lemma level is the level at which lexical-semantic and grammatical information is specified (but see following); the lexeme level is where the phonological and orthographic forms of a word are specified. Also, most models assume some type of parallel activation mechanism for lexical access (Caramazza, 1988; Dell, 1986; Jescheniak & Levelt, 1994; Morton, 1969; Roelofs, 1992; but see Forster, 1994, for a defence of search models).

Within the boundaries of these assumptions about the architecture of the lexical system, there are several hotly debated questions. One set of issues concerns what is represented at each of the hypothesised levels of processing; for example, is lexical-semantic information represented at the lemma level or are lemmas abstract nodes whose only function is to link semantic, grammatical, and lexical form information? Another set of issues concerns the nature of the mechanisms of access to lexical forms; for example, are lexical forms activated in parallel or is each form discretely activated? Yet another set of issues concerns the relations among the various components implicated in lexical processing; for example, does the activation of lexical-orthographic forms (orthographic lexemes) depend on the prior activation of lexical-phonological forms (phonological lexemes)? These issues are obviously inter-related: the type of answer one gives to any one of these questions has implications for the others. And, as might be expected, there is no agreement on most of these crucial aspects of the organisation and processing structure of the lexical system. In this paper we address some of these issues through the analysis of the lexical processing performance of an aphasic patient with damage at the level of lexical-semantic knowledge. The principal focus will be the relations among lexical components.

Virtually all the research on lexical access for word production has been concerned with speech production. Much of the research has exploited the production of slips of the tongue (Dell & Reich, 1981; Fromkin, 1971; Garrett, 1975, 1980; Shattuck-Hufnagel, 1979, 1986; Stemberger, 1985) and malapropisms (e.g. Fay & Cutler, 1977; see review in Levelt, 1989). However, there are also data from the tip-of-the-tongue phenomenon (Brown & McNeil, 1966; see A. Brown, 1991, for review), reaction time experiments (e.g. Jescheniak & Levelt, 1994; Levelt et al., 1991), and speech production disorders (e.g. Caramazza & Hillis, 1990; Martin, Dell, Saffran, & Schwartz, 1994; Martin, Weisberg, & Saffran, 1989; see Garrett, 1992, for review). By contrast, there is almost no research on the mechanisms of orthographic word production, and the little that there is has mostly been ignored in discussions of the organisation and processing structure of the lexical system. This is unfortunate, because there are a number of unresolved issues about the lexical system that can be illuminated by considering spelling performance in relation to speech production. Especially informative in this regard is the differential performance in spelling and speaking in subjects with lexical processing disorders. The contrasting patterns of performance in speaking and spelling can be used to identify the locus of functional damage within the lexical system and, in turn, the pattern of errors in each form of output can then be used to constrain claims about the types of representation and processing structure at specific levels of the system.

Consider in this context the issue of how lexical orthographic forms are accessed. If one were to assume that access of orthographic lexemes depended on the prior activation of their phonological counterpart, we would expect that an impairment in retrieving phonological forms should result in a corresponding deficit in retrieving orthographic forms. However, there is a large literature showing that the ability to spell is not infrequently spared in the face of severe impairment in phonological production (e.g. Alajouanine & Lhermitte, 1960; Assal & Buttet, 1981; Basso, Taborelli, & Vignolo, 1978; Caramazza, Berndt, & Basili, 1983; Ellis, Miller, & Sin, 1983; Hier & Mohr, 1977; Lecours & Rouillon, 1976; Lhermitte & Dérouesné, 1974; Patterson & Shewell, 1987). This dissociation has been interpreted as indicating that orthographic lexemes can be activated directly from lexical-semantics, bypassing the phonological lexicon (e.g. Allport & Funnell, 1981). However, this conclusion is not warranted unless it could be shown that the deficit in speech production is the result of direct damage to the phonological lexicon and not the result of damage to the post-lexical phonological processes. This reservation renders the mere observation of superior spelling performance relative to oral production theoretically uninformative for the purpose of determining whether orthographic production depends on some form of phonological mediation. However, there are a number of observations that cannot be so readily dismissed. For example, Caramazza and Hillis (1990) reported the performance of two brain-damaged subjects who made semantic errors in oral naming but not in written naming.

The fact that the subjects made semantic errors in the oral naming task restricts the locus of deficit to a lexical component of the system; the fact that they were able to retrieve the correct lexical form in spelling demonstrates that access of these lexical forms is not mediated by prior access of phonological lexemes. In other words, phonological and orthographic lexemes can be activated independently by lexical-semantic information (see Rapp & Caramazza, in press, for discussion of other relevant evidence).

Having argued for the autonomy of orthography in lexical access, we may now ask whether we can use the brain-damaged subjects' differential patterns of errors in producing written and spoken language to help decide finer-grained questions about the structure of the lexical system. Two issues will be considered: the relation of orthography to phonology and the relation between lexical-semantics and lexemes.

The evidence against the phonological mediation hypothesis of lexical orthographic access merely establishes that phonological mediation is not *necessary* for successful access of orthographic lexemes; it does not exclude other possible relations between phonological and orthographic forms, including direct activation between the two lexical components (as proposed, for example, by Allport & Funnell, 1981, and Patterson & Shewell, 1987). Another way in which phonological and orthographic outputs may constrain each other is through activation from sublexical transcoding mechanisms. That is, it is possible that the activated phonological and orthographic lexical forms are converted sublexically into orthographic and phonological representations, respectively. These nonlexical phonological and orthographic strings, in turn, activate the phonological and orthographic lexicons (as proposed by the summation hypothesis advanced by Hillis & Caramazza, 1991, and Patterson & Hodges, 1992). Thus, although the available evidence does not require that spelling is necessarily mediated by phonology, it does not exclude the possibility that phonology plays a highly constraining role in normal spelling.

Another issue that may be illuminated by considering the contrast in performance between spelling and speaking concerns the relation between lexical semantics and lexical forms. For example, as already noted, the occurrence of semantic errors only in speaking or only in writing in some brain-damaged subjects allows us to infer a locus of damage in lexical production at a point past the semantic component and before post-lexical processes. If this inference were correct, we would also be able to conclude that the normal semantic system (which, by hypothesis, is intact in these subjects) activates multiple, semantically related entries in the phonological and orthographic lexicons, creating the basis for semantic errors in the activation of lexemes (Caramazza & Hillis, 1990). This conclusion, in its most general form, is consistent with current models of lexical access in production (Bock & Levelt, 1994; Dell, 1990). However, there are two ways (at least) in which a semantic error may result from damage in accessing lexical forms from an intact semantic compo-

ment: Either because there are multiple entries active at the lexical-semantic level (and each entry activates its corresponding lexeme in the phonological and orthographic lexicons) and damage in accessing lexical forms results in the selection of a semantically related lexeme, or because a single, correct lexical-semantic representation activates multiple, semantically related lexemes and damage to the access process results in the selection of an incorrect lexeme from the set of activated entries. Which of these two hypotheses is most consistent with available evidence depends in part on how we articulate the relation between lexical semantics and lexical forms. We return to this issue in the Discussion. For now, we simply want to point out that the analysis of contrasting performance in spelling and speaking may contribute to our understanding of the mechanisms of lexical access.

The preceding discussion has shown that one way to address the issue of the relation between lexical components is to investigate the performance of brain-damaged subjects who make semantic errors in speaking and/or writing. As already noted, the presence of this type of error in lexical production is especially valuable because it can only result from damage to lexical components of the system. That is, unlike neologisms and other phonological or orthographic errors, which can have both lexical and nonlexical causes, by their very nature semantic errors can only result from damage to lexical components of the system. Thus, we can take the presence of semantic errors as indicating a deficit to one or another component of the lexical system; since their cause is lexical in origin, the analysis of the pattern of these errors in spelling and speaking can be used to constrain claims about the organisation and access of lexical knowledge. In this report we analyse the performance of a brain-damaged subject whose semantic errors in speaking and spelling could be shown to result from damage to the lexical-semantic component. The investigation focuses on a peculiar aspect of the subject's performance: It was observed during clinical testing that he would sometimes orally produce a word different from the one he was writing. Thus, for example, he was noticed to be uttering "piano" while writing *organ*. If confirmed experimentally, this type of error implies a complete independence of orthographic and phonological lexemes.

CASE HISTORY

Patient WMA is a right-handed farm owner, with a high-school education. He suffered from an intracerebral haemorrhage on August 28, 1990. The resulting haematoma was surgically removed 10 days later. The patient was first seen 4 years post onset, and was tested between June and October, 1994.

The neurological examination revealed a dense right hemiplegia. On double simultaneous stimulation, frequent extinction phenomena on the right were demonstrated in all modalities (tactile, visual, and auditory). An MRI per-

formed at the time of the present study revealed an extensive hypodensity in the deep anterior and central structures of the left hemisphere, corresponding to the site of the old haemorrhage; a marked atrophy of the frontal, temporal, and parietal cortices; and a conspicuous enlargement of the left lateral ventricle. Representative slices of the MRI are reported in Fig. 1.

NEUROPSYCHOLOGICAL EVALUATION

WMA scored within normal limits on Raven's Coloured Progressive Matrices, as well as on tasks of visual memory and constructional abilities. Limb praxis was mildly-to-moderately impaired. A severe buccofacial apraxia was present. Tasks requiring visual-spatial analysis demonstrated a mild, but clear, right-sided neglect. Because of the severe language disorder, verbal memory tasks requiring spoken output could not be administered. In memory probe tasks that require the ability to decide whether or not a word spoken by the examiner is included in a list presented a few seconds earlier, WMA performed relatively well but clearly worse than normal controls: in trials with 4, 6, and 8 words, he produced 20/24, 19/24, and 19/24 correct responses, respectively. In a similar task that used bisyllabic nonwords as stimuli, WMA also scored below normal (19/24 correct responses to series of 4 stimuli, and 16/24 to series of 6 stimuli). In both tasks, misses were more frequent than false alarms on short series; the reverse error distribution was observed on long series.

LANGUAGE EVALUATION

WMA's language abilities were tested by means of the BADA (Miceli, Laudanna, Burani, & Capasso, 1994). Performance on the battery demonstrated a very severe language deficit that involved multiple levels of language organisation.

Tasks Exploring Sublexical Orthography and Phonology

WMA was mildly impaired on a phoneme discrimination task with simple CV syllables. Although he produced a normal number of correct responses (57/60, or 95%) on this task, on 12 occasions he arrived at the correct response only after a second presentation of the stimulus.

Our subject was at chance level on a task that requires the ability to match an auditorially and a visually presented CV syllable (35/60 correct responses, 58.3%).

Nonword transcoding tasks were severely impaired. WMA produced 4/36 correct responses in repetition (11.1%), 6/45 in reading aloud (13.1%), and 0/25 in writing to dictation. All correct responses in repetition and in reading aloud were produced to monosyllabic stimuli; he failed to reproduce correctly any

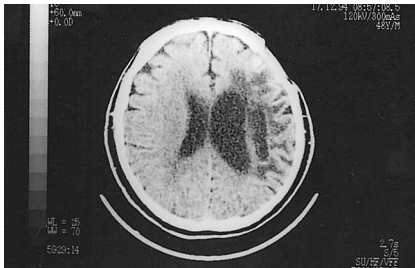
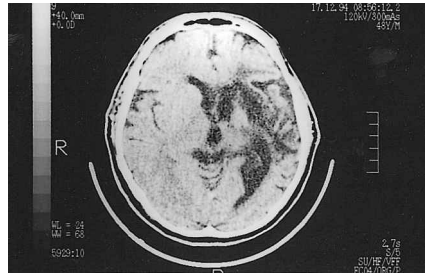
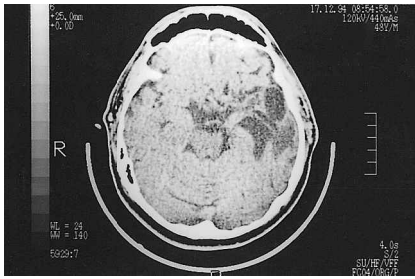


FIG. 1. Representative cuts of the CT scan, performed approximately 4 years post onset. Pictures show a massive, deep lesion of the left hemisphere, involving the globus pallidus, the putamen, the head of the caudate nucleus, possibly the thalamus, the internal and external capsule, as well as the white matter of the frontal, temporal, and parietal lobe. The lesion extends almost to the convexity of the hemisphere, and is associated with atrophy of the adjacent gyri, and with a marked dilation of the left ventricle.

bisyllabic or trisyllabic stimulus. A qualitative error analysis demonstrated that performance in repetition differed substantially from performance on the other tasks. In repetition, incorrect responses bore a phonological relationship to the stimulus (WMA repeated /ga'live/ as /ga'line/, and /ra'kone/ as /pa'lore¹); in reading and spelling, incorrect responses were often unrelated to the stimulus (WMA read *tena* as /ta'lante/, and wrote /kos'pivo/ as *nefa*). In reading aloud, WMA produced 39 incorrect responses (out of 45 stimuli, 86.9%), of which 16 (35.6% of total responses) resulted in words. Some of these were visually related to the stimulus (*validia* → “volare,” to fly), whereas others could be construed as the result of the activation of a word visually similar to the stimulus nonword, followed by a semantic substitution. For example, WMA read *ru* as “uccello,” bird, presumably as the result of access to the visual representation *gru* (crane), followed by a semantic substitution. A similar error is *noste* → (*notte*, night) → “letto,” bed. In writing to dictation, all incorrect responses were nonwords, and there was a very mild tendency to perseveration. Accuracy of responses to pseudowords was also measured on the basis of the percentage of letters reproduced correctly in each task. Only polysyllabic stimuli were included in this analysis. WMA reproduced correctly 50/79 (63.3%) letters in repeating 16 pseudowords; 56/165 (33.9%) letters in reading aloud 30 pseudowords; and 5/60 (8.3%) letters in writing 10 pseudowords to dictation. Since performance on tasks that required a spoken response was also affected by a moderate dysarthria, the figures reported for repetition and reading aloud must be taken only as the best possible approximation, but not as a precise measure. Even with these limitations, however, it is clear that WMA performed much more accurately on repetition than on reading aloud and writing to dictation.

Tasks Exploring the Lexical-semantic Level

Auditory lexical decision was marginally impaired (74/80 correct responses, 92.5%); WMA made the correct decision on 36/40 words (90%) and on 38/40 nonwords (95%). Performance on a visual lexical decision task was severely impaired (54/80 correct responses, 67.5%); WMA responded correctly to 23/40 words (57.5%) and to 31/40 nonwords (75.5%).

Word transcoding tasks were severely impaired. WMA produced 4/45 correct responses in repetition (8.9%), 10/92 in reading aloud (10.9%), and 5/46 in writing to dictation (10.8%). In all tasks a length effect was observed. However, this effect did not reach significance, because performance on all

¹ Throughout the present paper the following notations are used: stimuli presented visually and written responses are italicised; auditory stimuli and spoken responses are reported in quotation marks if they are words, and in phonetic transcription if they are nonwords; names of pictures presented for oral and written naming are neither italicised nor in quotes.

tasks was almost at floor. As with nonwords, performance in repetition differed qualitatively from that in reading aloud and in writing to dictation. In repetition, all incorrect responses were phonemically related to the target ("campanelli," little bells → /tampa'pElli/). In reading aloud, some incorrect responses were related visually/phonemically to the stimulus (*motore*, engine → /po'tore/, nonword). In many cases, however, WMA either failed to respond altogether to the stimulus (especially to long, low-frequency words), or produced a semantic paralexia (*poltrona*, armchair → "divano," sofa; *monumenti*, monuments → "antico," ancient). Some incorrect responses resulted from a failure to process correctly the right half of the stimulus (consider *bersaglio*, target → "borsa," purse; *gioia*, joy → "gioielli," jewels; *però*, but → "pera," pear). A fair number of incorrect responses resulted in morphological errors of the derivational type (*fucilati*, executed by firing squad → "fucile," rifle) and, more frequently, of the inflectional type (*freccie*, arrows → "freccia," arrow). The origin of these errors is unclear, as they might result from a deficit in morphological processing or from right-sided neglect. In writing to dictation, failures to respond and unrelated responses ("quindi," thus → *allacia*, nonword) accounted for most of the errors. In some cases, WMA produced semantic paraphrasias, as in "intanto," meanwhile → *circa*, almost. Several incorrect responses resulted in spelling errors that frequently affected the right side of words (e.g. "volpe," fox → *volpa*, nonword), and occasionally took the form of inflectional errors ("vigne," vineyards → *vigna*, vineyard).

On a task requiring the ability to match an auditorially or visually presented word to one of two pictures (the correct response and a semantic or a visual/phonemic foil), WMA showed a mild but definite impairment. He produced 36/40 correct responses in the auditory task (90%), and 37/40 in the visual task (92.5%). In the auditory task, he chose 3/20 semantic foils and 1/20 phonemic foils incorrectly; in the visual task he selected 2/20 semantic foils and 1/20 visual foils incorrectly.

In picture naming tasks, WMA performed very poorly. He produced orally 8/30 correct responses to objects (26.7%), and 4/28 to actions (14.2%); in written naming, he responded correctly to 1/22 objects (4.5%), and to 1/22 actions (4.5%). The overall number of segmentally correct responses on these tasks was so low as to prevent a reliable assessment of WMA's difficulty in selecting the appropriate lexical form. To obtain such an estimate, phonetically and/or phonemically deviant, but clearly recognisable responses in oral naming (e.g. "sigaretta," cigarette → /si'retta'/; "morde," he bites → /'vorde/), graphemic errors in written naming (e.g. *telefono*, telephone → *telefone*; *zucca*, pumpkin → *zacca*) and inflectional errors (two in oral naming and five in written naming—e.g. 'foglia,' leaf → "foglie," leaves; *albero*, tree → *alberi*, trees) were scored as correct; responses that unequivocally indicated failure to select the appropriate word form (semantic substitutions, circumlocutions, failures to respond) were scored as incorrect; and neologistic responses were

not counted (a response was considered to be neologistic when it contained less than 50% of the letters of the expected target, in the expected sequence—e.g. *fiocco*, ribbon → /ko'teto/; *maniglia*, door handle → *chechi*). With this scoring procedure, WMA produced correct oral responses to 14/30 objects (46.7%) and to 8/28 actions (29.6%), and correct written responses to 11/20 objects (55%) and to 3/19 actions (15.8%). Overall, he produced a comparable number of correct responses in oral and in written naming (22/58, or 37.9%, vs. 14/39, 35.9%), but responded much more accurately to objects than to actions (25/50 correct responses, 50%, vs. 11/47, 23.4%; $\chi^2 = 6.291$; $P < .02$). In object naming, WMA produced many semantic errors (window → “door”; cradle → *baby*); in action naming, most failures to select the correct target resulted in the production of a semantically related noun (lick → “ice cream”; sew → *needle*).

Tasks Exploring Sentence Processing

WMA performed poorly on grammaticality judgement tasks when the stimulus was presented auditorially (33/48 correct responses, 68.7%) and even worse when the stimulus was presented visually (8/24 correct responses, 33.3%).

When asked to repeat or to read aloud sentences, WMA failed to produce any correct response. All errors resulted in fragmented responses, in which free-standing grammatical morphemes (and frequently also major-class lexical items) were omitted and bound grammatical morphemes were substituted by other morphemes.

WMA also performed poorly in a sentence comprehension task requiring the ability to match a simple declarative sentence presented in the active or in the passive voice to one of two pictures, one representing the correct response, and the other representing the reversal of thematic roles, a morphological alternative, or a lexical-semantic alternative. He only produced 42/60 correct responses (70%) with auditorially presented sentences and 26/45 correct responses (57.8%) with visually presented sentences. He inappropriately chose 9/20 thematic foils (45%), 6/20 morphological foils (30%), and 3/20 lexical-semantic foils (15%) in the auditory task; 10/15 thematic foils (66.7%), 7/15 morphological foils (46.7%), and 2/15 lexical-semantic foils (13.3%) in the visual task. Across presentation modality, he was equally accurate with active (32/53 correct responses, 60.4%) and with passive sentences (36/52 correct responses, 69.2%).

Oral production tasks proved extremely difficult for WMA, whose speech was dysarthric, effortful, slow, and hypophonic. Very few (if any) correct grammatical structures could be identified in the transcripts of his picture description performance; he tended to produce one-word utterances or sequences of isolated words (usually nouns), devoid of free-standing grammatical morphemes and without a clearly recoverable syntactic structure. For example, presented with the picture of a car hitting a motorbike, he said: “Botta . . . auto

... motoretta ... botta," which roughly translates as "Crash (noun) ... auto ... motorbike ... crash (noun)." Connected written production was impossible.

Summary of the Language Screening Tasks

WMA made semantic errors in word–picture matching tasks and in picture naming tasks. He also made many semantic errors in reading aloud and in writing to dictation, but not in repetition. His abilities to convert print to sound and sound to print were severely impaired, whereas repetition was relatively spared. WMA's performance on the screening battery reveals a complex cognitive impairment, involving damage to sublexical conversion procedures (albeit to different extents) and the lexical-semantic system².

MORE DETAILED INVESTIGATION OF WMA'S DEFICIT(S)

In order to specify more precisely the nature of WMA's lexical processing deficit, he was asked to perform several tasks with the same set of 130 picturable nouns. The nouns belonged to 11 semantic categories (body parts, clothing, professions, animals, food, fruits and vegetables, furniture, tools, kitchen tools, transportation, musical instruments). Twenty nouns (body parts = 5; professions = 5; food = 4; clothing = 3; animals = 3) were in the high-frequency range (160–40/million); the remaining 110 ($N = 10$ in each category) were in the low-frequency range (15–1/million).

The 130 nouns were used in the following tasks: auditory and visual word–picture matching, oral and written picture naming, reading aloud, repetition, writing to dictation, and delayed copy. No more than one task was administered in each testing session. Because we were interested in identifying the source of semantic errors, only responses that clearly resulted from failure to retrieve a lexical form were considered to be incorrect. Hence, phonetic and phonemic deviations (in tasks that required spoken output) and minor spelling errors (in tasks that required written output) were scored as correct responses. WMA's few inflectional errors (five in reading aloud, six in writing to dictation, eight in written naming, and four in oral naming) were also scored as correct for present purposes. No derivational errors were observed in these tasks. Separate counts were made of semantic substitutions (foot → *elbow*), omissions, and neologisms (kangaroo → *scormano*, correct response *canguro*). WMA also produced incomplete responses (*autobus* → /au/ ...) or short words that bore no obvious phonemic or semantic relationship to the stimulus. These

² WMA also suffers from a visual input processing disorder that results in consistently poorer performance on tasks requiring the ability to process written input than on tasks requiring the ability to process auditory input. Because this deficit is not the focus of the present paper, it will not be discussed in detail.

responses were classified as unscorable. Performance on these tasks is shown in Table 1.

Auditory and Visual Word–Picture Matching

The examiner presented WMA with a picture while at the same time pronouncing a word (in the auditory task) or showing a written word (in the visual task). WMA was asked to say whether or not the word and the picture matched. Each picture was paired (on separate sessions) with the target word, with a semantically related word, or with an unrelated word. Thus, for example, the picture of a pear was paired with the word pear, or with the word orange, or with the word telephone. The order of presentation of the various word–picture pairs and the stimuli were varied randomly. In each session, the entire set of experimental words was administered, and approximately the same number of correct words, semantic foils, and unrelated foils was presented. The three sessions needed to complete each task were spaced at least one week apart. An item was scored as not having been comprehended correctly when the patient produced one or more incorrect responses to the three administrations of that item.

WMA was clearly impaired in the auditory (102/130, or 78.5%) and the visual task (103/130, or 79.2%). With one exception (in the auditory task), he never made more than one error on the same item and never accepted an unrelated word as the correct label for the stimulus picture. Errors resulted either from rejecting the correct word (3 times in the auditory task, 4 times in the visual task), or from incorrectly accepting a semantically related word as the correct label for the presented picture (26 times in the auditory task, 23 times in the visual task)³.

³ WMA performed much less accurately on these tasks than in the word comprehension tasks administered in the screening procedure. This discrepancy can be accounted for by the different demands of the two types of tasks. In the screening task, WMA was presented with a word, and had to select the response by pointing to one of two pictures. In order to respond correctly on this task, he had to compare the semantic information provided by the word with that provided by the two pictures. This procedure may have resulted in correct responses even in the presence of damaged semantic information. For example, presented with “dog” and with the pictures of a dog and of a cat, WMA may have responded correctly because, even though he did not activate sufficient semantic information to select the picture of a dog, he knew that “dog” is not appropriate for the picture of a cat. In the task reported here, he was required to say whether a picture and a word matched. In this case, in order to respond correctly, WMA had to compare the semantic information activated by the picture with that activated by the word, and to evaluate whether they constituted a reasonable match. This paradigm offers greater opportunity for incorrect responses. For example, failure to activate the semantic representation of dog may have resulted both in an incorrect rejection of “dog,” and in an incorrect acceptance of “cat” as the correct match.

TABLE 1

Performance Obtained by WMA in Processing the Same 130 Words in the Context of Various Tasks. Incorrect Responses Resulting in Phonetically/Phonemically Related Errors, Spelling Errors, or Inflectional Errors Were Scored as Correct (Percentages Are in Parentheses)

	<i>Correct</i>	<i>Semantic</i>	<i>Omissions</i>	<i>Neologisms</i>	<i>Unscorable</i>
Word-Picture matching					
Auditory	102(78.5)	28(21.5)	–	N/A	–
Visual	103(79.2)	27(20.8)	–	N/A	–
Oral naming	78(60.5)	39(30.0)	10(7.7)	2 (1.6)	1(0.8)
Written naming	57(43.8)	35(27.0)	7(5.6)	27(20.8)	4(3.1)
Reading aloud	101(77.7)	21(16.2)	4(3.1)	4 (3.1)	–
Writing to dictation	71(54.6)	33(25.4)	1(0.8)	22(17.0)	3(2.3)
Repetition	126(96.9)	3 (2.3)	1(0.8)	–	–
Delayed copy	122(93.8)	5 (3.8)	–	3 (2.3)	–

Oral and Written Picture Naming

WMA produced 78/130 (60.5%) correct responses in oral naming, and 57/130 (43.8%) in written naming. Roughly the same numbers of semantic substitutions (39 and 35, respectively, or 30% and 27% of total responses) and of omissions (10 and 7, respectively, or 7.7% and 5.6% of total responses) were observed in the two tasks. The major difference between the oral and the written task resulted from neologistic responses being produced often in written naming (27, or 20.8% of total responses), but very infrequently in oral naming (2, or 1.6% of total responses).

Transcoding Tasks

Results obtained in the screening battery pointed to an impairment of the lexical-semantic system, and of orthography-phonology and phonology-orthography sublexical conversion procedures, with spared phoneme(input)-phoneme(output) conversion procedures. Consistent with the view that semantic errors in reading, spelling, and repetition only occur when both lexical and sublexical conversion procedures are damaged, WMA produced semantic errors in reading aloud and in writing to dictation, but not in repetition (nor in delayed copy). The performance observed with the 130 words used for this task is consistent with that observed in the screening procedure.

Reading aloud resulted in 101 correct responses (77.7%), 21 semantic substitutions (16.2% of total responses), 4 omissions (3.1%), and 4 unscorable responses (3.1%). Writing to dictation was severely impaired. WMA responded correctly to 71 words (54.6%), made semantic errors to 33 (25.4%), and produced 22 neologistic responses (17%). He also produced five unscorable responses (3.8%) and one omission (0.8%).

Performance on repetition was markedly different from reading aloud and writing to dictation. WMA repeated correctly 126 words (96.9%). He produced three semantic substitutions (2.3%) and failed to respond to one stimulus (0.8%). However, errors scored as semantic were also phonologically related to the target. “Autobus” was reproduced as the short (but commonly used) form “auto”; “cinta” (belt) as the synonym “cinghia” (belt); to “baffi” (moustache), WMA produced the sequence “/bakki/.../pappi/.../sbalbi/.../babbi/...sbarbi” (you shave)⁴.

In all tasks except repetition (and delayed copy), WMA scored somewhat more accurately on high- than on low-frequency items. A significant effect of frequency was found when the tasks that yielded semantic errors (word–picture matching, picture naming, reading aloud and writing to dictation) were considered ($\chi^2 = 7.635$, $P < .01$), but not when each task was considered separately, nor when all tasks were lumped together ($\chi^2 = 0.007$, $P = \text{n.s.}$).

Performance was also influenced to some extent by semantic category. Repetition and delayed copy were excluded from this analysis, due to the absence of unambiguous semantic errors. Foods and animals were relatively less impaired, and body parts relatively more impaired than professions, clothing, fruits and vegetables, kitchen tools, and musical instruments.

The following analyses were aimed at identifying the cognitive damage responsible for the occurrence of semantic errors. These errors may arise either from damage to the semantic component or from a deficit in accessing lexical forms (Caramazza & Hillis, 1990)⁵. In order to evaluate the two possibilities, item-specific effects were investigated, by contrasting the degree of consistency for each item across all tasks. Item-specific effects could arise from a single source or from multiple sources. In the first case, they would have to be construed as the result of semantic damage (the semantic component is the only component shared by all comprehension and production tasks); as a consequence, items that result in semantic errors in one task should result in semantic errors in all tasks (excluding those where relatively spared sublexical procedures would block such errors). In the second case, item-specific effects would result from the independent impairment of modality-specific components of

⁴ A similar picture was observed in delayed copy. WMA was presented with a written word, and was allowed to look at it until he felt confident that he could reproduce it. He was then instructed to remove the stimulus, and to copy it after approximately 10 seconds. WMA reproduced correctly 122 words (92.3%). He produced five responses that were scored as semantic errors (3.8%) and three neologisms (2.3%). As in repetition, “semantic” errors were also visually similar to the target. For example, WMA copied *salame* (pepperoni) as *saluma* (a nonword string that is similar to both the target and to *salumi*—a term that refers to all types of salted pork meat). He never produced incorrect responses that were semantically related but graphemically unrelated to the target.

⁵ The locution “deficit in accessing lexical forms” is intended agnostically to refer either to damage to access procedures or damage to lexical forms, making them inaccessible for output.

the lexical system; as a consequence, the same item may be difficult in one (or more than one) task, but is less likely to be difficult in all tasks.

In order to establish whether semantic errors resulted from a single source in the case of WMA, his performance on the tasks that resulted in semantic errors was used to test for the presence of interdependence among tasks. On the assumption of a single cause for all the semantic errors, we would expect interdependence among tasks. As a first step in this analysis, the distributions of various error types in each of the six tasks under consideration were examined. These distributions were used to calculate the expected incidence of a given number of incorrect responses to the same item, based on the hypothesis of no interdependence across tasks (Coltheart & Funnell, 1987; Hillis, Rapp, Romani, & Caramazza, 1990). Separate estimates were made of the occurrence of semantic substitutions only, of semantic substitutions and omissions, of semantic substitutions, omissions, and neologisms, and of all errors. These estimated values were compared with the actual incidence of errors in WMA's performance. For example, the expected incidence of exactly 0, 1, 2, 3, 4, 5, or 6 semantic substitutions to the same item across the six tasks was compared to the observed incidence of 0, 1, 2, 3, 4, 5, or 6 semantic substitutions⁶. Results of these analyses are shown in Table 2. Independent of the error types used in the analysis (semantic substitutions only; semantic substitutions and omissions; semantic substitutions, omissions, and neologisms; all error types), observed and expected occurrence are significantly different (P always $\rightarrow .001$), rejecting the hypothesis of no interdependence. That is, this result does not support the hypothesis that damage to independent mechanisms determines WMA's performance, and favours the alternative account, that damage to just one component, involved in all the tasks included in the analysis, is responsible for the observed distribution of errors. Since the semantic component is the only component shared by the six tasks considered for this analysis, the results invite the conclusion that semantic damage is responsible for the errors produced by WMA (see Hillis et al., 1990, for more detailed discussion of this argument).

To conclude, then, the observed pattern of performance—very poor performance in reading nonwords aloud and in writing nonwords to dictation; semantic errors in word–picture matching tasks, in naming tasks, in reading words aloud and in writing words to dictation—results from damage to the semantic component of the lexical system, and from damage to sublexical phonology–orthography and orthography–phonology conversion mechanisms.

⁶ For example, the expected probability of two semantic errors to the same item was calculated by summing all permutations that would result in two errors on that item: $(P_1 \times P_2 \times Q_3 \times Q_4 \times Q_5 \times Q_6) + (P_1 \times Q_2 \times P_3 \times Q_4 \times Q_5 \times Q_6) + (P_1 \times Q_2 \times Q_3 \times P_4 \times Q_5 \times Q_6) + (P_1 \times Q_2 \times Q_3 \times Q_4 \times P_5 \times Q_6) + (P_1 \times Q_2 \times Q_3 \times Q_4 \times Q_5 \times P_6) + (\dots) \times 130$. In this formula, P corresponds to the probability that WMA would make a semantic error in a given task, and Q to the probability that he would not make a semantic error in a given task, and the numbers 1 to 6 correspond to the six tasks under consideration.

TABLE 2
Observed and Expected Incidence of a Given Number of Incorrect Responses Produced to the Same Item in the Course of Six Experimental Tasks (Percentages Are in Parentheses)

No. of Errors	Types of Errors											
	Semantic		Semantic+Omissions		Sem.+Om.+Neologisms		All Errors		Semantic		All Errors	
	Expected	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected	Observed
0/6	22(16.9)	47(36.1)	18(13.8)	41(31.5)	8 (6.1)	26(20.0)	7 (5.4)	24(18.5)	—	—	—	—
1/6	43(33.1)	23(17.7)	39(30.0)	25(19.2)	28(21.5)	27(20.8)	27(20.8)	29(22.3)	—	—	—	—
2/6	32(24.6)	31(23.8)	34(26.1)	31(23.8)	37(28.5)	27(20.8)	37(24.5)	20(15.4)	—	—	—	—
3/6	31(23.8)	19(14.6)	34(26.1)	17(13.1)	47(36.1)	31(23.8)	48(36.9)	33(25.4)	—	—	—	—
4/6	2 (1.5)	9 (6.9)	4 (3.1)	14(10.8)	8 (6.1)	12 (9.2)	9 (6.9)	16(12.3)	—	—	—	—
5/6	—	1 (0.8)	1 (0.8)	2 (1.5)	2 (1.5)	6 (4.6)	2 (1.5)	7 (5.4)	—	—	—	—
6/6	—	—	—	—	—	1 (0.8)	—	1 (0.8)	—	—	—	—
χ^2	21.502		23.722		18.247		22.980					
P	<.001		<.001		<.001		<.001					

EXPERIMENTAL STUDY

A subject with the pattern of cognitive/linguistic impairments reported for WMA (semantic damage in the presence of abolished orthography–phonology and phonology–orthography conversion procedures) provides a unique opportunity to test whether writing requires phonological mediation or whether orthographic and phonological lexical representations are activated independently. The two hypotheses make different predictions concerning the types of errors that should occur when the subject is asked to produce two consecutive responses (one spoken, one written) to the same picture. Under the phonological mediation account, semantic damage will result at times in the activation of a semantically incorrect phonological lexical representation. Since under this hypothesis the activation of orthographic representations is driven by phonological information, the incorrectly activated phonological representation will activate the corresponding orthographic representation. Hence, written output should always be “lexically consistent” with spoken output. By “lexically consistent” it is meant that the subject either should respond correctly in both modalities, or, when in error, should produce the same incorrect word in both modalities. For example, given the picture of a tiger, he might fail to respond in both output modalities, or might produce two semantic substitutions resulting in the same word (lion → “tiger” → *tiger*). The hypothesis also predicts that errors resulting in lexically “inconsistent” responses should not occur. For example, a correct spoken response should never be followed by a semantic substitution (lion → “lion” → *tiger*) or by a failure to respond (lion → “lion” → ...); a semantic substitution or an omitted response should never be followed by the correct response (lion → “tiger” → *lion*; lion → “...” → *lion*), and, in the case of two semantic substitutions, responses should never result in different words (lion → “tiger” → *leopard*). The hypothesis of orthographic autonomy, by contrast, predicts that both lexically consistent and lexically inconsistent errors should occur in the event of semantic damage. On this account, impoverished semantic information will activate sets of conceptually related lexical representations independently in the phonological and in the orthographic lexicon. If the same entry (or no entry) reaches threshold in both output systems, lexically consistent responses will occur. If, on the other hand, the lexical representation most active in the phonological component differs from that most active in the orthographic component (or, if an entry reaches threshold in an output system, whereas none of the activated representations reach threshold in the other), lexically inconsistent responses will be produced.

Anecdotal observations of WMA's behaviour during the administration of the screening battery are consistent with the orthographic autonomy account. WMA sometimes produced an unsolicited response in one modality before responding in the required modality. On some occasions, the two responses

resulted in different words. For example, in writing to dictation “scarpe,” shoes, WMA kept repeating to himself “scarpe” while at the same time writing *calze*, socks; in written naming, to the picture of pincers, he kept saying “pinze,” pliers, while writing *sega*, saw; and, in oral naming, to the picture of an organ, he said “suona,” plays, while tracing with a finger the word *piano*. These errors are, at face value, problematic for the hypothesis that writing requires phonological mediation. Later we explore in detail the relation between spoken and written responses.

In order to contrast the phonological mediation and the orthographic autonomy hypotheses, the ideal experiment would require the subject to produce spoken and written responses simultaneously to each stimulus. Such a task would provide information on the lexical representations available in the phonological and in the orthographic output lexicons at a given moment. However, this task could not be administered since WMA wrote very slowly (he used his left hand because of right hemiplegia) and spoke very slowly, due to a severe dysarthria. Thus, tasks that required two consecutive responses to the same stimulus, one spoken and one written, were administered.

Performance on Immediate, Across-modality Picture Naming Tasks

Two tasks were administered. In the first task, WMA was asked to say, then write, the name of a picture; in the second task, the response order was reversed. In both tasks, the stimulus remained in view until both responses had been produced. The patient was given no feedback as to the correctness of his responses. Whenever he attempted to produce more than one response, only the last attempt was scored. The 130 pictures used in the tasks described in the previous section were used in this and the following tasks.

Overall performance on the two tasks is shown in Table 3. The number of correct responses and of semantic and unscorable errors is comparable in the two tasks. Neologisms are much more frequent in spelling than in speaking (12.3% vs. 2.3% in the oral-then-written task; 13.1% vs. 1.5% in the written-then-oral task), whereas failures to respond are more frequent in speaking than in spelling (10% vs. 1.5% in the oral-then-written task; 8.5% vs. 0.8% in the written-then-oral task)⁷. Further analyses considered performance across modalities of output.

⁷ The different distribution of neologisms and of omissions as a function of response modality might reflect different constraints on the minimal amount of information required to support output in the oral as opposed to the written modality. Extremely reduced phonological information may not suffice to allow spoken output—for example, the phoneme sequence /b[-]t[-]l[m[-]a/ may be blocked either because it is too distant from the intended target, or because it is unpronounceable. By contrast, the same amount of information might still allow a written response, as there are no motoric constraints preventing the output of BTMA.

TABLE 3
 Overall Performance in the Two Across-modality Picture
 Naming Task (Percentages Are in Parentheses)

	<i>Oral-then-Written</i>		<i>Written-then-Oral</i>	
	<i>Oral</i>	<i>Written</i>	<i>Written</i>	<i>Oral</i>
Correct	77(59.2)	69(53.1)	69(53.1)	83(63.8)
Semantic	36(27.7)	40(30.8)	39(30.0)	34(26.2)
Neologism	3 (2.3)	16(12.3)	17(13.1)	2 (1.5)
No response	13(10.0)	2 (1.5)	1 (0.8)	11 (8.5)
Unscorable	1 (0.8)	3 (2.3)	4 (3.1)	-

On both tasks, WMA produced many lexically inconsistent responses. Examples of sequences resulting in a correct response and in an incorrect response are presented in Table 4. The first quantitative analysis considered the number of stimuli to which WMA produced either two correct responses or two incorrect responses, and the number of stimuli to which he produced a correct-then-incorrect response, or an incorrect-then-correct response (Table 5). He produced consistently correct, or consistently incorrect responses to 90 (69.2%) items in the oral-then-written picture naming (resulting from 53 pairs of correct responses and from 37 pairs of incorrect responses, corresponding to 40.8% and to 28.5% of total responses, respectively), and to 86 (66.2%) items in the written-then-oral picture naming (resulting from 54 pairs of correct responses and from 32 pairs of incorrect responses, corresponding to 41.6% and to 24.6% of total responses, respectively). The inconsistent responses in oral-then-written picture naming (30.8%) resulted from 24 correct spoken responses followed by incorrect written responses and from 16 incorrect spoken responses followed by correct written responses; in written-then-oral naming the inconsistent responses (33.8%) resulted from 15 correct written responses followed by incorrect spoken responses and from 29 incorrect written responses followed by correct spoken responses. A breakdown of these sequences by error type is reported in Table 6. In the oral-then-written naming task, the correct-then-incorrect sequences resulted from correct responses being followed by 14 semantic substitutions, by 1 failure to respond, by 7 neologisms, or by 2 unscorable responses; the incorrect-then-correct sequences resulted from the correct response being preceded by a semantic substitution ($N = 8$), by a failure to respond ($N = 5$), or by a neologism ($N = 3$). In the 44 lexically inconsistent responses observed in the written-then-oral naming task, correct responses were followed by a semantic error ($N = 10$), by a failure to respond ($N = 4$), or by a neologism ($N = 1$), and were preceded by a semantic substitution ($N = 15$), by a failure to respond ($N = 1$), by a neologism ($N = 12$) or by an unscorable response ($N = 1$).

TABLE 4
 Across-modality Picture Naming Tasks: Examples of
 Response Sequences Resulting in One Correct, One Incorrect
 Response

<i>Oral-then-Written Naming</i>		
<i>Picture</i>	<i>Oral Response</i>	<i>Written Response</i>
tromba (trumpet)	“orchestra” (orchestra)	+
baffi (moustache)	+	<i>barba</i> (beard)
vino (wine)	No response	+
pasta (pasta)	+	No response
piedi (feet)	/djommike/ (neol)	+
gomito (elbow)	+	<i>smeggio</i> (neol)

<i>Written-then-Oral Naming</i>		
<i>Picture</i>	<i>Written Response</i>	<i>Oral Response</i>
scarpa (shoe)	<i>calza</i> (socks)	+
farfalla (butterfly)	+	“libellula” (dragonfly)
suora (nun)	No response	+
pera (pear)	+	No response
stivali (boots)	<i>gimeto</i> (neol)	+
mantello (cape)	+	/ven' tado/ (neol)

TABLE 5
 Incidence of Various Response Sequences in the Two
 Across-modality Picture Naming Tasks (Percentages Are in
 Parentheses)

<i>1st Response</i>	<i>2nd Response</i>	<i>Oral-then-Written</i>	<i>Written-then-Oral</i>
Correct	Correct	53(40.8)	54(41.6)
Correct	Incorrect	24(18.5)	15(11.5)
Incorrect	Correct	16(12.3)	29(22.3)
Incorrect	Incorrect	37(28.4)	32(24.6)

TABLE 6
 Immediate, Across-modality Naming Tasks: Breakdown of
 Sequences Resulting in a Correct Response Followed by an
 Incorrect Response, or in an Incorrect Response Followed by a
 Correct Response

	<i>Oral-then-Written</i>	<i>Written-then-Oral</i>
<i>Correct response followed by</i>		
Semantic substitution	14	10
Failure to respond	1	4
Neologism	7	1
Unscorable response	2	–
<i>Correct response preceded by</i>		
Semantic substitution	8	15
Failure to respond	5	1
Neologism	3	12
Unscorable response	–	1

This pattern of results is problematic for the phonological mediation hypothesis. Production of the correct phonological word form should always result in the activation of the corresponding orthographic word form and, barring damage directly to the orthographic lexicon or more peripheral processes, in the correct written response. The production of a semantic error in writing after the production of the correct spoken response cannot easily be explained by the phonological mediation hypothesis⁸. Even more damaging for this hypothesis are the 15 correct written responses followed by a lexically incorrect oral response (11.5% of total responses). These cases simply cannot be explained by the phonological mediation hypothesis, as that assumes that the activation of an orthographic representation is driven by the prior activation of its associated phonological word form, and thus a correct written response presupposes the activation of the correct phonological form.

⁸ A correct spoken response followed by a semantic error in the presence of semantic damage may still be accounted for under phonological mediation, if a complex set of assumptions is made. Impoverished semantic information activates multiple phonological representations, and by chance the correct response is produced. At the same time, all the phonological forms activated by impoverished semantic information (and not just the form that has just reached threshold) pass activation on to the corresponding orthographic forms, one of which (different from the one that has just reached threshold in the phonological output system) is produced. Of course, the last step is only possible if an entry that does not reach threshold in the phonological system can activate the corresponding orthographic entry above threshold. This would be possible if the phonological and orthographic lexemes corresponding to the same lemma are associated with very different levels of activation. But, since under phonological mediation an orthographic form can *only* be activated by its corresponding phonological form, it is difficult to see how the activation level of phonological and orthographic lexemes can be so different.

Analysis of the actual responses produced by WMA in those trials in which he failed to produce either the correct spoken response or the correct written response to the same stimulus (Table 5) provides further support for the orthographic autonomy hypothesis. In the oral-then-written and in the written-then-oral picture naming tasks there were 18/37 (48.7%) and 10/32 (31.2%) instances, respectively, in which WMA produced different types of incorrect responses to the same stimulus. For example, in oral-then-written naming, he produced no spoken response to doctor, but wrote *drugs*; in another instance, he responded “scodella” (soup dish) to spoon, and immediately thereafter wrote the uninterpretable response *mendrona*. Similarly, in written-then-oral naming, he correctly wrote *chin* to the corresponding picture, but then said “elbow”; and, presented with a picture of scissors, wrote *tailor* but was unable to produce any written response. When sequences resulting in two semantic substitutions were considered, 6/19 (31.6%) and 7/22 (31.8%), in the oral-then-written naming and in the written-then-oral naming task, respectively, responses were inconsistent. Examples are shown in Table 7.

Overall, in the oral-then-written naming task, only 66/130 sequences (50.8%) resulted either in the same word (correct or semantically incorrect), or in the same type of incorrect response (two neologisms, or two failures to respond). The remaining 64/130 sequences (49.2%) resulted in lexically inconsistent responses (a correct and an incorrect word, two semantically incorrect words, or a failure to respond followed or preceded by a correct word, an incorrect word, or a neologism). In the written-then-oral naming task, compa-

TABLE 7

Across-modality Picture Naming Tasks: Examples of Incorrect Responses Resulting in Two Different Semantic Substitution Errors

<i>Oral-then-Written Naming</i>		
<i>Picture</i>	<i>Oral Response</i>	<i>Written Response</i>
cuoco (cook)	“pietanza” (food)	<i>forchette</i> (forks)
pollice (thumb)	“mignolo” (little finger)	<i>mani</i> (hands)
tenaglia (pliers)	“pinza” (pincers)	<i>sega</i> (saw)
<i>Written-then-Oral Naming</i>		
<i>Picture</i>	<i>Written Response</i>	<i>Oral Response</i>
caviglia (ankle)	<i>piede</i> (foot)	“gamba” (leg)
fisarmonica (accordion)	<i>zampogna</i> (pipes)	“grammofono” (gramophone)
peperoni (peppers)	<i>pomodoro</i> (tomato)	“carciofo” (artichoke)

rable results were obtained: WMA produced 69/130 (53.1%) lexically consistent responses and 61/130 (46.9%) lexically inconsistent responses.

At face value, the observations reported in the previous paragraphs cannot be accounted for by the phonological mediation hypothesis, and invite the conclusion that orthographic word forms are represented and activated autonomously from phonological word forms. However, an alternative explanation of the observed data that is consistent with the phonological mediation hypothesis must be ruled out before a firm conclusion is reached.

Lexically "inconsistent" responses may have occurred for reasons that have nothing to do with orthographic independence. Suppose that WMA suffered from a deficit characterised by the abnormally rapid decay of activated representations. If this were the case, the phonological mediation hypothesis could still account for inconsistent oral and written responses to the same item. Sequences like those reported in Tables 6 and 7 can be explained as follows. When producing the first response, the stimulus picture activates a semantic representation, which activates a phonological representation that is selected for output. When producing the second response, because of the abnormal decay of the previously activated representation, the just-activated semantic and lexical information is no longer available, and the process must start anew. The stimulus again activates semantic information, which activates a phonological output representation, which in turn activates the corresponding orthographic output representation. If the semantic representation or the phonological output representation differ from those activated in the first attempt at responding, two different responses may be produced. Thus, within the framework of the phonological mediation hypothesis, the assumption of an abnormally rapid decay of activated representations can account for the observed response sequences.

This hypothesis, however, relies on the assumption that the information activated in producing the first response has no effect on the production of the second response, independent of whether the two responses are produced in the same or in different modalities. This allows an obvious prediction: Consistency of responses to the same item in within-modality naming tasks should be comparable to that observed in across-modality naming tasks. In fact, abnormally fast decay of activated representations should affect performance on both types of tasks similarly—i.e. by lowering response consistency to the same extent, irrespective of whether the two responses must be produced in the same or in different modalities.

The orthographic autonomy hypothesis, by contrast, can easily accommodate the association of across-modality inconsistency and within-modality consistency. In the presence of semantic damage, the independent activation of phonological and orthographic word forms results in lexically inconsistent responses. By contrast, when two responses in the same modality are required, the semantic and the lexical information activated during the first attempt will

still be above their resting state when the second response has to be produced; as a consequence, the lexical form produced during the first attempt is more likely to be produced than any other form.

Performance Obtained by WMA on Picture Naming Tasks that Require the Production of Two Consecutive Responses in the Same Modality

In order to verify the predictions based on the hypothesis of abnormal decay of activated representations, two tasks were administered. The first task required two consecutive spoken responses; the second task required two consecutive written responses. The 130 pictures used for the previous tasks served as stimuli.

For the oral-then-oral picture naming task, WMA was asked to name the picture. After he had produced his response, the picture was withdrawn and the subject was asked to count aloud backwards from five to zero. Subsequently, the picture was shown again and WMA was asked to name it a second time. This procedure was intended to prevent him from responding by simply repeating the first response, and to ensure that the two responses resulted from separate attempts at naming the stimulus. For the written-then-written naming task, the stimulus picture and WMA's written production were removed as soon as WMA completed his first response. Five seconds later, the picture was shown again, and WMA was asked to produce the second response. It was assumed that the second response was unlikely to result simply from the reiteration of a motoric sequence, given WMA's laborious writing.

The overall results obtained by WMA on these tasks are shown in Table 8. An almost perfect level of consistency is observed (Table 9). In 129/130 (99.2%) trials, WMA produced either two correct responses (86 in the oral task, 66.2%; 81 in the written task, 62.3%) or two incorrect responses (43 in the oral task, 33.1%; 48 in the written task, 36.9%). Incorrect responses always resulted in errors of the same type (two failures to respond, two semantic substitutions, two neologisms, etc.). Furthermore, almost all semantic errors resulted in the same incorrect response being produced twice. Only one exception each was observed in the oral-oral and written-written conditions: In the oral task, WMA made the semantic error shoes → "para" (rubber sole) followed by the correct response "scarpe"; in the written task, his first response to organ was the neologistic sequence *anedede*, followed by the neologism *obano* (correct response: *organo*), which was scored as correct. The occurrence of lexically consistent vs. inconsistent responses on the two within-modality picture naming tasks is significantly different ($\chi^2 = 91.4$, $P \rightarrow .001$) from the occurrence of the same response types on the two across-modality picture naming tasks.

The virtually perfect consistency of responses in the within-modality condition rules out the possibility that the inconsistent responses on the across-

TABLE 8
Overall Performance in the Two Within-modality Picture Naming
Tasks (Percentage Are in Parentheses)

	<i>Oral</i>		<i>Written</i>	
	<i>Oral 1</i>	<i>Oral 2</i>	<i>Written 1</i>	<i>Written 2</i>
Correct	86(66.2)	87(66.9)	81(62.3)	82(63.1)
Semantic	40(30.8)	39(30.0)	32(24.6)	32(24.6)
No response	3 (2.3)	3 (2.3)	–	–
Neologism	1 (0.8)	1 (0.8)	11 (8.5)	10 (7.7)
Unscorable	–	–	6 (4.6)	6 (4.6)

TABLE 9
Incidence of Various Response Sequences in the Two
Within-modality Picture Naming Tasks (Percentages
Are in Parentheses)

<i>1st Response</i>	<i>2nd Response</i>	<i>Oral</i>	<i>Written</i>
Correct	Correct	86(66.2)	81(62.3)
Correct	Incorrect	1 (0.8)	1 (0.8)
Incorrect	Correct	–	–
Incorrect	Incorrect	43(33.1)	48(36.9)

modality tasks reported earlier resulted from an abnormally rapid decay of activated representations. This leaves, as the main candidate explanation for the inconsistent responses in speaking and spelling, the hypothesis that orthographic and phonological lexemes are activated independently by the damaged lexical semantic component. But, if this were the case, we would also expect that inconsistency of responses should be observed not only across modalities of output but also within the same modality on different occasions. In the within-modality naming task reported earlier, the two responses were produced too closely together in time for us to observe inconsistencies between responses. In such tasks, the form selected as the first response is still very likely to be the most active a few seconds later, when the second response must be produced. A different outcome is expected when the two responses are spaced by a long interval (i.e. days or weeks). In this case, whatever changes were induced in the pattern of semantic-lexical activation during the first naming trial will have subsided; thus, during the second trial the form produced on the first attempt should be no more likely to be selected than other, semantically related forms. To evaluate properly whether different responses would be produced within a modality on different occasions, we could consider naming responses produced in different testing sessions. To this purpose, we reanalysed WMA's performance on the various administrations of the oral and of the written picture naming tasks.

TABLE 10

Summary of Overall Performance on the Administration of the Picture Naming Task in the Same Modality Used to Assess Delayed, Within-modality Response Consistency (Percentage Are in Parentheses)

	<i>Oral Naming</i>			<i>Written Naming</i>		
	<i>Session a</i>	<i>Session b</i>	<i>Session c</i>	<i>Session a</i>	<i>Session b</i>	<i>Session c</i>
Correct	78(60.0)	77(59.2)	86(66.2)	57(43.8)	69(53.1)	81(62.3)
Semantic	39(30.0)	36(27.7)	40(30.8)	35(26.9)	39(30.0)	32(24.6)
Neologism	2 (1.5)	3 (2.3)	2 (1.5)	27(20.8)	17(13.1)	12 (9.2)
Omission	10 (7.7)	13(10.0)	2 (1.5)	7 (5.4)	1 (0.8)	–
Unscorable	1 (0.8)	1 (0.8)	–	4 (3.1)	4 (3.0)	5 (3.9)

Session a: “canonical” task; Session b: first response to the immediate, across-modality task; Session c: first response to the immediate, within-modality task.

Performance on Delayed, Across-modality Picture Naming Tasks

The data used in this analysis were those obtained in the various naming tasks already reported (e.g. the first response produced in the immediate, within-modality task and the first response in the oral–written naming task). The three oral and the three written tasks—sessions a, b, and c—had been administered at approximately one-month intervals.

Performance on the various test sessions, as reported in Tables 1, 3, and 9, are summarised in Table 10. Consistency of overall performance is high. More correct responses are produced in the later-administered tasks, probably due to extensive practice with the experimental set⁹. However, the incidence of semantic substitutions is stable across sessions of the same task, and is comparable across tasks (it ranges between 27.7% and 30.8% in oral naming, and between 24.6% and 30% in written naming).

In order to measure performance consistency, responses produced in sessions a and b, and responses produced in sessions b and c, were paired. Because there were no marked differences in performance across test sessions, analyses were carried out on the 260 pairs resulting from collapsing sessions a–b and sessions b–c for the oral task, and on the 260 pairs resulting from collapsing sessions a–b and sessions b–c for the written task.

⁹ It should be stressed that not all the tasks administered to WMA are reported here. The 130 word list was used also in the context of transcoding tasks requiring dual (reading aloud–writing; repetition–writing; writing to dictation–repetition) and triple responses (repetition–writing–repetition; writing to dictation–repetition–writing; reading aloud–writing–repetition; delayed copy–repetition–writing). Thus, each word was spoken and spelled several times by WMA.

For each task, the number of items to which WMA produced two correct responses, two incorrect responses, or a correct response and an incorrect response, is reported (Table 11). To facilitate comparison, Table 11 also reports the same data for the immediate, within-modality tasks (see also Table 9), and for the immediate, across-modality tasks (see also Table 4). Analysis of the 260 response pairs in the oral naming task yielded 196/270 (75.4%) pairs of consistent responses, resulting from 126 (48.5%) pairs of correct responses and 70 (26.9%) pairs of incorrect responses, and 64/260 (24.6%) pairs of inconsistent responses, resulting from 27 correct-then-incorrect sequences (10.4%) and from 37 incorrect-then-correct sequences (14.2%). The same analysis for written naming showed very similar results: 188/260 (72.3%) pairs of consistent responses, resulting from 103 (39.6%) pairs of correct responses and 85 (32.7%) pairs of incorrect responses, and 72/260 (27.7%) pairs of inconsistent responses, resulting from 24 correct-then-incorrect sequences (9.2%) and 48 incorrect-then-correct sequences (18.5%).

There are two aspects of the results in Table 11 that are relevant for our present purposes. First, the observation that 64/260 (24.6%) pairs in the delayed, oral naming task and 72/260 (27.7%) pairs in the delayed, written naming task yielded inconsistent responses stands in stark contrast with the virtual absence of inconsistent responses in the immediate, within-modality oral (1/130, 0.8%) and written naming tasks (1/130, 0.8%)—see Table 9. The statistical comparison of immediate vs. delayed, within-modality naming is highly significant, both for the oral task ($\chi^2 = 42.5$; $P \rightarrow .001$) and for the written task ($\chi^2 = 48.7$; $P \rightarrow .001$). Second, the number of inconsistent responses observed in delayed, within-modality naming is very similar to that observed in the immediate, across-modality naming tasks (oral-then-written: 37/130, or 28.4%; written-then-oral: 32/130, or 24.6%)—see Table 4. And in fact, non-significant differences are obtained when comparing delayed, oral naming with immediate, oral-then-written naming ($\chi^2 = 0.038$; $P = \text{n.s.}$), or delayed, written naming with immediate, written-then-oral naming ($\chi^2 = 0.036$; $P = \text{n.s.}$)¹⁰.

The consecutive semantic substitutions produced by WMA in the delayed, within-modality tasks were also analysed (Table 12—this table also shows the corresponding data for the other two tasks, to facilitate comparison). WMA produced consecutive semantic substitutions to 38 stimuli in the oral task, and to 37 stimuli in the written task. Of these, 19/38 in the oral task (50%) and 12/37 in the written task (32.8%) resulted in different words. These values are significantly different from those observed in the immediate, within-modality tasks, in which consecutive semantic substitutions resulted in the same word

¹⁰ Note that item consistency in the delayed, within-modality condition was also comparable across tasks (oral vs. written naming: $\chi^2 = 0.442$; $P = \text{n.s.}$). This observation further supports the notion that the cognitive lesion in WMA damages a component that affects performance equally in oral and written naming—the semantic component.

TABLE 11
 Delayed, Within-modality Picture Naming Task: Incidence of Various Response Sequences Observed in the Oral
 and the Written Task (Percentages are in Parentheses)

<i>1st Resp</i>	<i>2nd Resp</i>	<i>Delayed, Within-modality</i>		<i>Immediate, Within-modality</i>		<i>Immediate, Across-modality</i>	
		<i>Oral</i>	<i>Written</i>	<i>Oral</i>	<i>Written</i>	<i>Oral, then Written</i>	<i>Written, then Oral</i>
Correct	Correct	126(48.5)	103(39.6)	86(66.2)	81(62.3)	53(40.8)	54(41.6)
Correct	Incorrect	27(10.4)	24 (9.2)	1 (0.8)	1 (0.8)	24(18.5)	15(11.5)
Incorrect	Correct	37(14.2)	48(18.5)	-	-	16(12.3)	29(22.3)
Incorrect	Incorrect	70(26.9)	85(32.7)	43(33.1)	48(36.9)	37(28.4)	32(24.6)

Results of the same analysis for the immediate, within-modality (from Table 9) and for the immediate, across-modality (from Table 4) task are also reported.

TABLE 12
 Response Consistency on the Same Items in the Delayed, Within-modality Picture Naming Task (Percentages are in Parentheses)

	<i>Delayed, Within-modality</i>		<i>Immediate, Within-modality</i>		<i>Immediate, Across-modality</i>	
	<i>Oral</i>	<i>Written</i>	<i>Oral</i>	<i>Written</i>	<i>Oral, then Written</i>	<i>Written, then Oral</i>
Same word	19(50.0)	25(67.6)	39(100)	32(100)	12(66.7)	14(63.6)
Different words	19(50.0)	12(32.8)	–	–	6(33.3)	8(36.4)
Total	38 (100)	37 (100)	39(100)	32(100)	18 (100)	22 (100)

The cases in which WMA produced two semantic substitutions in response to the same picture are analysed, and the number of responses resulting in the same semantically incorrect word and in two different semantically incorrect words is reported. The figure of the same analysis conducted on immediate, within- and across-modality tasks is also reported for comparison.

almost without exception (oral naming: $\chi^2 = 20.6$; $P \rightarrow .001$; written naming: $\chi^2 = 11.08$; $P < .001$). By contrast, response consistency for consecutive semantic substitutions was comparable in the delayed, within-modality tasks and in the immediate, across-modality tasks (delayed oral naming vs. immediate, oral-then-written naming: $\chi^2 = 1.004$; $P = \text{n.s.}$; delayed written naming vs. immediate, written-then-oral naming: $\chi^2 = 0.001$; $P = \text{n.s.}$). Thus, the results demonstrate that similar forms of inconsistent responses are obtained in the delayed, within-modality and the immediate, across-modality naming conditions.

DISCUSSION

The results we have reported for WMA can be summarised succinctly: (1) He makes semantic errors in all word comprehension and production tasks as well as in those transcoding tasks where sublexical conversion procedures are severely damaged; and (2) he frequently produces inconsistent written and oral responses in the same naming trial. The facts in (1)—that WMA makes semantic errors in all comprehension and production tasks—imply that he has a deficit to the lexical-semantic component (see Hillis et al., 1990, for a similar case); the fact that he produces different oral and written responses in the same naming trial disconfirms the phonological mediation hypothesis of written production, and supports the hypothesis that phonological and orthographic lexemes are independently activated by lexical semantic information (for a different case and similar arguments see Rapp, Benzing, & Caramazza, this issue).

The hypothesis of phonological mediation in spelling predicts that there should be a close correspondence between the orthographic and phonological

lexemes produced in the same trial in a naming task. More specifically, the prediction is that the same *lexical* response must be produced in spelling and speaking¹¹. This expectation was clearly disconfirmed in WMA. He frequently produced inconsistent lexical responses in spelling and speaking, including cases where an incorrect phonological lexeme was followed by a correct orthographic lexeme, and cases where a semantic error in speaking was followed by a different semantic error in spelling. These two types of errors cannot be accommodated in any straightforward manner within the phonological mediation hypothesis. However, the occurrence of inconsistent lexical errors in oral and written naming tasks receives a ready explanation within the orthographic autonomy hypothesis.

In the normal, unimpaired system, a lexical-semantic representation will normally maximally activate the correct phonological and orthographic lexical forms. That is, the semantic representation for CAT will correctly activate the phonological form /kæt/ and the orthographic form <cat>. Why, then, should damage to the semantic system lead to inconsistent responses in the two modalities of output? Why should it not lead to the same response in the two modalities, albeit an incorrect one, as it does in the case of correct responses? The answer to this question is tied to a more basic question: Why do subjects with damage to the semantic component make semantic errors at all? Our answer to the latter question is based on the following assumptions about the structure of the semantic component and its relation to lexical forms (see Caramazza & Hillis, 1990).

We have assumed that the meaning of a word is represented by a set of semantic features (or a set of nodes corresponding to meaning primitives). The semantic features activate all lexical forms whose meanings contain those features. Thus, for example, the semantic properties [has legs] and [living] will activate all lexical forms referring to living things and those referring to objects with legs, including such diverse things as dog, boy, hippopotamus, chair, and table¹². Under normal circumstances the lexical form that receives maximal activation is the correct one because it is the one with the largest number of connections to the activated meaning. On this view, the semantic representation of CAT will maximally activate the phonological and orthographic forms of

¹¹ The hypothesis allows responses to be different at the segmental level if post-lexical phonological or orthographic deficits are present. For example, the responses /kæt/ and /kæg/ 'cag or *cia* to a picture of a cat or to a picture of a dog (hence representing a semantic error) would be consistent with the phonological mediation hypothesis, as the spelling errors could be attributed to a post-lexical deficit.

¹² For illustrative purposes we have made the assumption that there is a single semantic property [has legs] that is shared by animate and inanimate objects. This assumption may be false—perhaps chairs and boys do not share the semantic property [has legs] because there are two distinct properties [has legs]: one referring to a property used for motion and the other referring to a property used for holding up surfaces.

“cat,” but will also activate, though to a lesser degree, the lexical forms for “dog” and “lion,” still less “hippopotamus” and “eagle,” and lesser still “chair.” However, if damage to semantic representations were to result either in the destruction of some of the semantic features or some type of generalised “noisiness” in the semantic network, one consequence would be that the active semantic representation would no longer maximally activate the correct lexical form but might activate a roughly equal number of semantically related forms. In this situation, the selection of a response could well depend on the momentary fluctuations of activation levels of the activated cohort of lexical forms (for cat these might include cat, dog, lion, pet, meow, ...). In other words, there will not be a systematic relationship between a stimulus and a response: Any one of several responses could be produced for a stimulus on any one occasion. If orthographic and phonological lexemes were activated independently by semantic representations, we would then expect that on some occasions the orthographic and phonological responses would be the same—both correct or both incorrect—and on other occasions one response would be correct and the other incorrect; and when both responses are incorrect, on some occasions the same incorrect response would be produced whereas on other occasions different incorrect responses would be produced. This is precisely the pattern of performance we have reported for WMA, which thus unequivocally supports the hypothesis that phonological and orthographic forms are autonomously represented and activated by semantic information.

We have presented compelling evidence in favour of the orthographic autonomy hypothesis. But if the orthographic and phonological lexicons were to be truly independent, as argued here, why is it that anomic disorders so often seem to involve both written and spoken forms? Why is it that the pattern of inconsistent semantic errors reported for WMA is not reported more frequently? A consideration of these issues requires a discussion of the relations among lexical components and those between lexical forms and sublexical phonology–orthography and orthography–phonology conversion processes.

There is a weak and a strong version of the orthographic autonomy hypothesis. The weak version holds that orthographic and phonological lexemes are directly and independently activated by lexical semantic representations, and that phonological and orthographic lexemes are directly connected to each other (e.g. as hypothesised by Allport & Funnell, 1981; and by Patterson & Shewell, 1987). The strong version holds only the first part of the conjunction; on this version of the orthographic autonomy hypothesis there are no direct connections between phonological and orthographic forms. The weak version of the hypothesis provides a ready account for the observation that there are brain-damaged subjects who produce inconsistent semantic errors in oral and written naming as well as for the observation that these cases may be rather rare. Because of the hypothesised connection between lexical forms, the activation of one lexical form—either phonological or orthographic—will lead to the

activation of its corresponding lexeme in the other modality. On this view, the selection of a lexeme in one modality involves both the direct activation from the semantic component and the indirect activation from its corresponding lexeme in the other modality. This type of lexical architecture guarantees that the same word is activated in the phonological and orthographic lexicons. An implication of this view is that selective damage to the semantic system would result in a deficit in oral and written naming, but because of the interaction between lexical forms the same lexical response is expected in the two modalities of output. In order to account for the production of inconsistent responses in oral and written naming, we would have to assume not only a deficit in the semantic component but also damage to the connections between lexical forms. Thus, by making different assumptions about the form of damage to the lexical system, the weak orthographic autonomy hypothesis can account both for cases such as WMA and for those cases where the same lexical errors are consistently produced in oral and written naming.

The strong version of the orthographic autonomy hypothesis could also account for consistent and inconsistent error patterns in oral and written naming tasks if we were to assume the summation hypothesis of lexical activation (Hillis & Caramazza, 1991; Miceli, Giustolisi, & Caramazza, 1991; Patterson & Hodges, 1992); that is, the hypothesis that phonological and orthographic lexical forms receive input both from the semantic component and from sublexical orthography–phonology and phonology–orthography conversion procedures, respectively. On this view, the interaction between orthographic and phonological lexical forms is mediated by sublexical conversion procedures. Thus, for example, the successful activation of /kæt/ makes available to the orthographic lexicon, through the sublexical phonology–orthography conversion process, candidate spellings that further constrain the selection of the orthographic lexeme <cat> activated from the semantic component. This type of lexical architecture also guarantees that the same word is selected in the phonological and orthographic lexicons. Thus, damage to the semantic component would result in consistent errors in oral and written naming, because the selection of a lexeme in the phonological or orthographic lexicon will *indirectly* affect the selection of the same word in the other lexicon. In order to account for the pattern of inconsistent errors in oral and written naming we must also assume severe damage to the sublexical orthography–phonology and phonology–orthography conversion processes. This latter damage would have the effect of completely isolating the orthographic and phonological lexicons from each other, with the consequence that damage to the semantic component would often result in the activation of different lexemes in the two production lexicons. Thus, just like the weak version of the orthographic autonomy hypothesis, the strong version of the hypothesis is also able to account for both consistent and inconsistent patterns of naming errors but does so by having to postulate multiple loci of damage to the lexical system and sublexical conversion processes.

The two hypotheses of the functional architecture of the lexical processing system embodied in the strong and weak versions of the orthographic autonomy hypotheses can be distinguished empirically. The strong version of the hypothesis predicts that inconsistent naming errors should only be produced by brain-damaged subjects who are severely impaired in sublexical conversion processing, as is the case in WMA. Further anecdotal information that would seem to favour the strong version of the orthographic autonomy hypothesis is provided by those cases who seem to be unable to name an object orally until they have produced some of the letters in the word, and also by those cases who seem to be unable to write the word until they have articulated the beginning of the word. Of course, these observations are only anecdotal but they are consistent with the performance profile we have reported for WMA. The strong version of the orthographic autonomy hypothesis would be disconfirmed if a subject with damage to the semantic component and spared sublexical conversion procedures were to produce inconsistent errors, or if a subject with damage to the semantic component and damaged sublexical procedures were to produce only consistent naming errors. Either pattern would demonstrate that sublexical conversion mechanisms play no (or a very minimal) role in allowing an interaction between phonological and orthographic lexemes. These observations would provide indirect support to the possibility that this interaction is subsumed by direct lexical links, as suggested by the weak version of orthographic autonomy. Further detailed investigations of other cases are needed to distinguish between the two versions of the orthographic autonomy hypotheses.

In conclusion, the results we have reported have implications for two aspects of lexical processing: the functional architecture of the lexical system and the dynamics of lexeme activation. With respect to the functional architecture of the lexical system, WMA's inconsistent semantic errors in oral and written naming provide compelling evidence against the phonological mediation hypothesis of lexical-orthographic access and suggest, instead, that orthographic lexemes are activated directly by lexical-semantic information. The data do not allow an unambiguous choice between the strong and weak versions of the orthographic autonomy hypotheses but they are consistent with the strong version. The results are also relevant to correct discussions about the dynamics of activation of lexical forms. The fact that WMA made different semantic errors in the same naming trial suggests that semantic representations activate multiple lexical forms in each lexical form component.

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