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The Autonomy of Lexical Orthography

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Do we need to access the spoken form of a word in order to retrieve the word's spelling or in order to understand the meaning of its written form? In this paper we focus on the relationship between lexical phonology and orthography *specifically in production* and we present the case of a neurologically impaired individual who is often unable to provide the correct spoken name of an object although he may be able to write its name correctly. We argue that this evidence is seriously problematic for the hypothesis of obligatory phonological mediation and conclude that orthographic lexical forms can indeed be independently accessed for production without the mediating role of phonology.

INTRODUCTION

Do we need to access the spoken form of a word in order to retrieve the word's spelling or in order to understand the meaning of its written form? This question concerns the extent to which orthographic and phonological lexical forms can be represented and processed *independently* and is central to our understanding of the fundamental relations amongst the various aspects of our word knowledge—orthographic-phonological-semantic-syntactic. Traditionally it has been assumed that written language skills and knowledge are entirely dependent upon spoken language knowledge and processes. This assumption is found both in work with individuals with acquired neurological deficits (Brown, 1972; Geschwind, 1969; Grashey, 1885; Head, 1926; Hecaen & Angelergues, 1965; Lichtheim, 1885; Luria, 1966; Wernicke, 1886) as well as in the study

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of normal subjects (in the context of writing see Frith, 1979; Hotopf, 1980; and for discussions of the issue with respect to reading see Perfetti & Bell, 1991; Van Orden, Johnston, & Hale, 1988). However, there are a number of lines of evidence from impaired performance indicating that phonological mediation is not required either in written comprehension or in written production (Ellis, 1982; Lhermitte & Déro uesné, 1974; Patterson & Marcel, 1977).

Here we will focus on the relationship between lexical phonology and orthography *specifically in production* and we will present the case of a neurologically impaired individual who is often able to write the name of a pictured object correctly in the face of a persistent inability to provide the correct spoken name of the object. For example, in response to a picture of a pear:

Examiner:	Can you write the name?
PW:	(writes) P-E-A-R
Examiner:	Can you say it?
PW:	Fruit . . . damn that's wrong. Piece of fruit that I love . . . uh, uh, uh . . . damn it . . .
Examiner:	Can you come up with the name?
PW:	I can sit here and spell it for you all day long . . .

This pattern of performance would seem to be problematic for a functional architecture in which access to phonology is a necessary prerequisite for access to orthographic lexical forms.

We will first review the various patterns of impaired performance that have been put forward in support of the autonomy of orthography and we will then consider objections that can, or have been, raised regarding each of them. Finally we will indicate how, with the case at hand, we will be able to address certain of these objections.

The Relationship between Lexical Orthography and Phonology

According to the obligatory *phonological mediation hypothesis*, written language is entirely parasitic upon spoken language. As a consequence, in reading one must go from a written stimulus to a phonological representation before one can gain access to the meaning of a word. Similarly, in writing one must retrieve the spoken form of a word in order to gain access to the graphemic form (see Fig. 1a). This hypothesis (sometimes referred to in reading as phonological recoding) is consistent with our introspective experiences of inner speech as well as with the fact that the development of written language has followed that of spoken language both in the species and the individual. Nonetheless these observations do not preclude the possibility that the adult

processing system is organised so that knowledge of the written and spoken forms of the language can be accessed independently. According to this alternative view, which we will call the *orthographic autonomy hypothesis* (Fig. 1b), orthographic knowledge can make contact with the more abstract aspects of lexical knowledge (such as meaning and syntax) *directly*, without phonological mediation. It is important to note that we are considering the issue of whether or not lexical (or sublexical) phonology is *required* for written language processing. Thus, evidence in support of a direct relationship between meaning and orthography does not rule out the possibility of *optional* phonological mediation either by means of lexical connections between orthography and phonology (Fig. 1c) or via sublexical processes (Fig. 1d). Questions concerning whether or not such optional processes exist and when, and to what extent, they are used are important and interesting issues, but distinct from the possibility of orthographic autonomy that we will explore here. We will return to this issue in the Discussion.

As would be predicted by the phonological mediation hypothesis, a large proportion of those individuals who exhibit impairments in spoken language also exhibit impairments of comparable or greater magnitude in written language production (Alajouanine & Lhermitte, 1960; Basso, Taborelli, & Vignolo, 1978; Head, 1926; Hecaen & Angelergues, 1965; Luria, 1966). Although consistent with phonological mediation, the finding of associated deficits can also be accounted for under the hypothesis of orthographic autonomy if we assume that the errors in the two output modalities are either the result of a deficit to shared levels of representation (such as to the lexical semantic store) or the consequence of two independent deficits affecting each of the written and spoken lexical stores. Thus, given that the association of deficits in written and spoken naming can be accounted for under either hypothesis, the truly informative finding would be that of spared knowledge of orthographic forms in the context of an impairment affecting phonological lexical forms. This pattern would be problematic for obligatory phonological mediation yet predicted by orthographic autonomy.

Establishing the Locus of Impairment: Lexical vs. Post-lexical

Clearly, however, not all observations of superior written vs. oral responding are relevant. For example, cases in which difficulties in oral responding result from motor difficulties affecting the articulators would be irrelevant. A number of cases exhibiting superior written vs. spoken naming with intact articulatory abilities have, in fact, been reported across a number of languages (Assal, Buttet, & Jolivet, 1981; Basso et al., 1978; Bub & Kertesz, 1982; Caramazza, Berndt, & Basili, 1983; Caramazza & Hillis, 1990; Coslett, Gonzalez-Rothi, & Heilman, 1984; Ellis, Miller, & Sin, 1983; Friederici, Schoenle, & Goodglass,

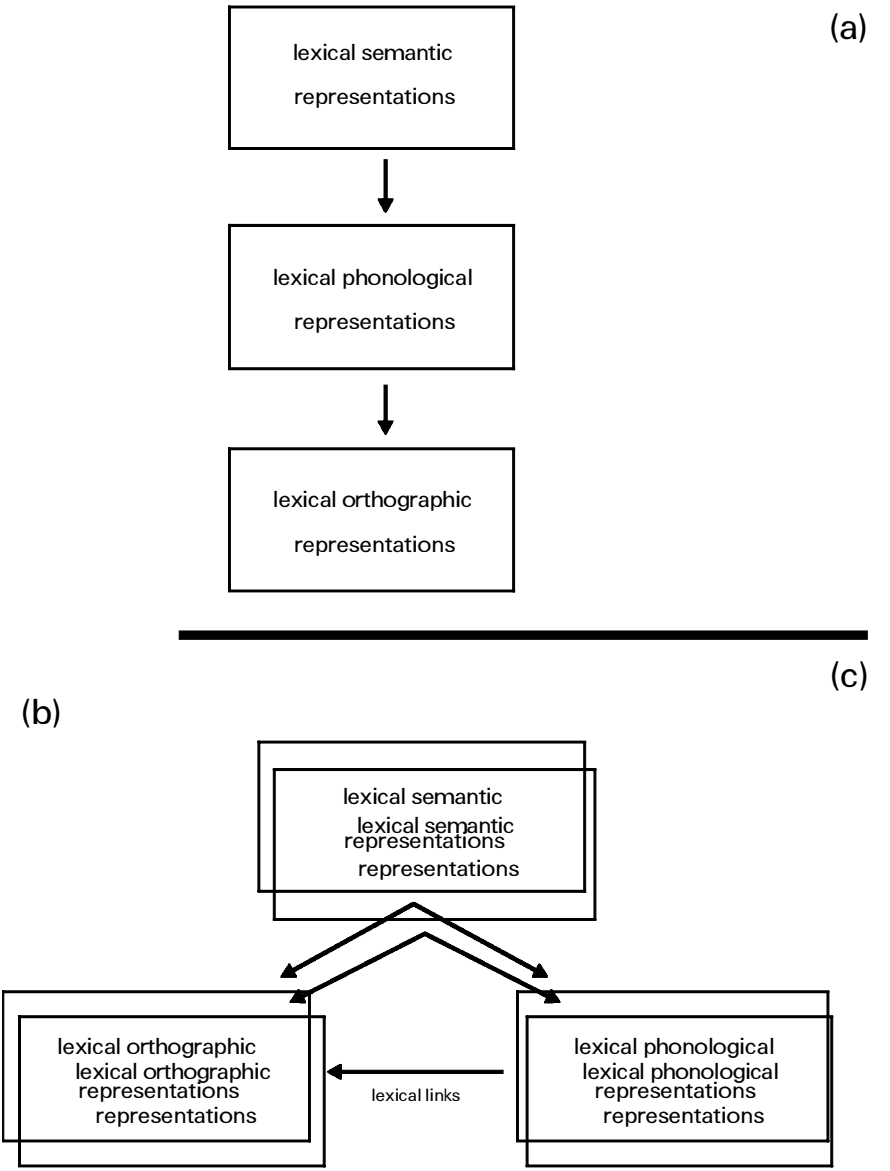

FIG. 1. Schematic representation of various possible relationships between lexical orthography and phonology: (a) obligatory phonological mediation; (b) orthographic autonomy.

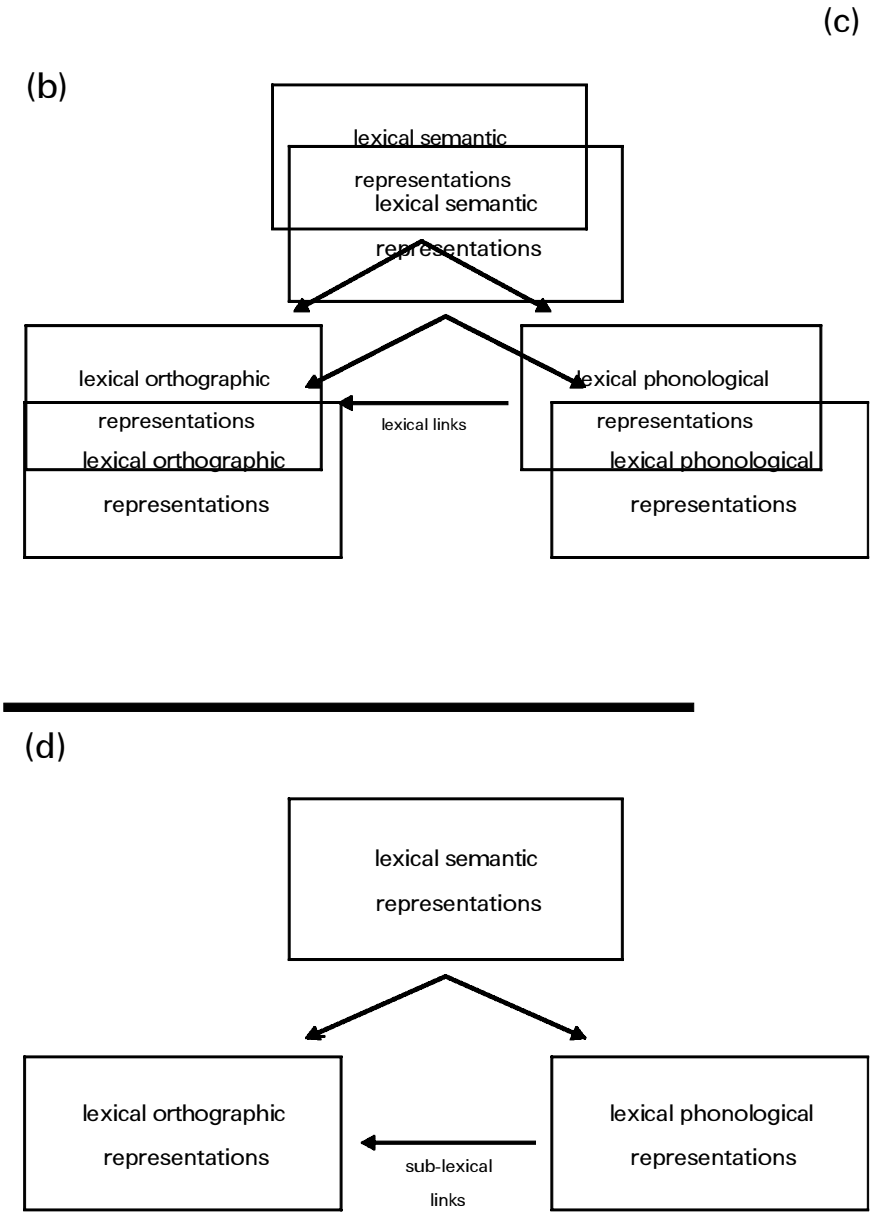

FIG. 1. Schematic representation of various possible relationships between lexical orthography and phonology: (c) orthographic autonomy + optional phonological mediation via lexical links; (d) orthographic autonomy+optional phonological mediation via sublexical links.

1981; Grashey, 1885; Hier & Mohr, 1977; Lecours & Rouillon, 1976; Leischner, 1969; Levine, Calvanio, & Popovics, 1982; Lhermitte & Dérouesné, 1974; Lichtheim, 1885; Mohr, Sidman, Stoddart, Leicester, & Morton, 1980; Mohr, Pessin, Finkelstein, Funkenstein, Duncan, & Davis, 1978; Nickels, 1992; Patterson & Shewell, 1987; Rapp & Caramazza, 1997; Semenza, Cipolotti, & Denes, 1992). However, although it is obviously necessary to rule out a peripheral articulatory source of the spoken errors, the finding of intact articulation is also insufficient. What is critical in determining if a pattern of superior written vs. spoken responding is problematic for the hypothesis of obligatory phonological mediation is that the spoken deficit be located at the level of phonological *lexical form*. Thus it is essential to establish that the source of spoken errors is lexical rather than post-lexical. In order to evaluate the relevance of any case of superior written vs. spoken responding with intact articulation, we must first determine if a lexical locus for the spoken errors can be established.

In reviewing the potentially relevant performance patterns that have been reported we will differentiate the patterns of superior written vs. spoken production according to the primary error type produced in spoken output: (1) phonemic/neologistic errors, (2) no responses, and (c) semantic paraphasias. To be clear: We make these distinctions because the different error types are subject to somewhat different objections regarding their evidential role in the phonological mediation/orthographic autonomy debate; they are not meant to imply specific claims regarding common or distinct functional etiology[1].

Phonemic Errors and Spoken Neologisms + Relatively Good Written Responding

There are a number of individuals who exhibit fluent, well-articulated speech characterised by neologisms and phonemic errors in the context of relatively spared written performance (Assal et al., 1981; Caramazza et al., 1983; Coslett et al., 1984; Ellis et al., 1983; Lhermitte & Dérouesné, 1974; Patterson & Shewell, 1987; Rapp & Caramazza, in press; Semenza et al., 1992). For example, one of the individuals described by Lhermitte and Déro uesné (1974) was 74% correct in written production but only 8% correct in oral production. Likewise, the Italian patient described by Semenza et al. (1992) was only 3% correct in oral naming of pictures and objects, but 85% in written naming. Another individual, PBS (Rapp & Caramazza, 1977), orally named the picture of a castle, which we will refer to as p(castle), as /krɛstIt/ but spelled the name

[1] For example, given our incomplete understanding of their origins within a functional architecture, it is possible that neologistic responses, phonemic errors, and no responses correspond to different points in a continuum of errors resulting from a common locus. Alternatively, it may turn out that these various error types have clearly distinct functional origins.

correctly; p(taxi) yielded /waz/ and T-A-X-I. Cases such as these are apparently problematic for the phonological mediation claim since it is difficult to argue that spoken neologistic responses form the basis for the retrieval of correct written responses; thus, it is hard to imagine how the phonological representations that support incorrect spoken responses (such as /waz/) also allow access to correct orthographic representations (such as T-A-X-I).

However, the considerable uncertainty regarding the functional origin of these nonarticulatory spoken errors (see Buckingham & Kertesz, 1976; Butterworth, 1992; Ellis et al., 1983) makes it difficult to establish unambiguously a specifically lexical locus of impairment in these cases. Thus, one could argue that in spite of the typically intact articulatory abilities of these individuals, their spoken errors 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 still could be maintained that intact phonological representations serve as the basis for the retrieval of the correct orthographic forms and that it is a subsequent deficit, specific to the phonological output system, that is responsible for the spoken error. Such an account would render these cases irrelevant to the issue of phonological mediation.

Ruling out a post-lexical impairment is not easy because accounts of post-lexical yet 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. Generally speaking, post-lexical/pre-articulatory stages include: (1) those processes/structures responsible for maintaining lexical phonological material in memory (Caramazza et al., 1983) during the course of (2) the application of procedures dedicated to developing the appropriate phonetic representations. These latter processes are assumed by some to involve the proper assignment of both segmental and prosodic material to specific positions within a syllabically organised word frame (Butterworth, 1979; Dell, 1989; Levelt, 1989; Shaffer, 1976; Shattuck-Hufnagel, 1987) as well as whatever elaboration may be required to generate appropriate allophones or (depending on one's theory) to flesh out underspecified lexical phonological forms (Archangeli, 1985; Kiparsky, 1982). Although it is unclear which specific performance features should result from disruption to these processes, Butterworth (1992) has suggested that post-lexical/pre-articulatory deficits might be expected to create particular difficulties with longer words and with specific phonemes and, additionally, that performance should be relatively unaffected by lexical frequency[2].

In spite of these interpretive difficulties, one could nonetheless argue for a lexical locus of impairment in at least some cases of phonemic errors/spoken

[2] Additionally, Butterworth has argued that lexical vs. post-lexical deficits could be distinguished by the consistency vs. inconsistency of responding. Elsewhere we have indicated some difficulties involved in the use of a consistency criterion (Rapp & Caramazza, 1993).

neologisms + good written responding on the basis of the observation that certain of these individuals exhibit little or no trouble in oral reading (Miceli & Caramazza, 1993) or repetition (Semenza et al., 1992). This observation would seem to make it difficult to claim that their phonological difficulties arise at a post-lexical stage. It would seem to indicate, instead, that the difficulty lies specifically in the retrieval of the lexical phonological forms themselves, as has more generally been argued (Butterworth, 1979). However, the counter-objection could be raised that improved performance in reading and repetition results from the fact that these tasks, unlike naming, allow for the contribution of nonlexical processing. That is, it could be argued that better performance is possible in reading and repetition because in these tasks phonological information generated by nonlexical processes dedicated to grapheme–phoneme conversion (in reading) and acoustic–phonology conversion (in repetition) can be used alone, or in combination with partial lexically derived material.

In sum, there are a number of cases involving phonemic and neologistic errors in the context of relatively intact written production that seemingly create difficulties for the phonological mediation hypothesis. The primary difficulty with these cases lies in convincingly ruling out a pre-articulatory, yet post-lexical, locus of the spoken production deficit.

No Response + Relatively Good Written Responding

There are also a number of individuals who typically produce no spoken response although they are able to write the names of a target either correctly or with sufficient accuracy that the written name is recognisable (e.g. Bub & Kertesz, 1982; Grashey, 1885; Hier & Mohr, 1977; Levine et al., 1982). For example, MH, whose performance was described by Bub and Kertesz (1982), was able to write the name of 15/20 objects correctly although she was able to name only 1/20 orally. Some of the written errors were clearly identifiable as the target word: p(salt) → S-A-L-K, p(pillow) → P-E-L-L-O-W. In addition to her inability to arrive at a spoken response, MH was also unable to make rhyme judgements about pictures whose names she couldn't produce (this was also observed in Hier & Mohr, 1977; and Levine et al., 1982). These cases have been interpreted as involving deficits affecting the retrieval of lexical phonological forms and have been considered to be problematic for the hypothesis of obligatory phonological mediation. Thus, it is argued that it seems unlikely that phonology could be required to access orthography when an individual, unable to come up with a spoken response or experience the sound of an intended target subjectively, is nonetheless able to write the name of the word correctly.

However, as in the cases involving neologisms and phonemic errors, a post-lexical locus of impairment might be entertained. One might argue that "don't know" responses result when phonemic distortions are generated and

either the patients are adept at self-monitoring and refrain from any production at all or the distortions are so severe that they cannot be articulated. In response, one could point out that under this scenario we would certainly expect to observe at least *some* evidence of phonemic distortion. Contrary to this expectation, the cases described by Bub and Kertesz (1982) and Grashey (1885) involved individuals who, although unable to name most open-class items orally, were otherwise able to speak without phonemic errors.

Although the absence of overt phonemic distortions in the speech produced by these subjects perhaps renders a post-lexical locus unlikely, the difficulties involved in unambiguously establishing a lexical origin of the spoken "don't know" responses remains a primary concern with this line of evidence.

Spoken Semantic Paraphasias + Good Written Responding

Although phonological errors and "don't know" responses may be ambiguous with respect to their lexical or post-lexical origin, semantic errors are typically not thought to be. It has been proposed that semantic errors in production may arise from either a semantic or lexical form level of damage (Caramazza & Hillis, 1990). Furthermore, in contrast to the difficulties involved in adjudicating between a lexical and a post-lexical locus for phonemic errors and "don't know" responses, the locus of semantic errors can often clearly be established by assessing the integrity of the subject's comprehension of misnamed items. For example, a subject who names a picture of a lion as "tiger" and describes it as a "cat with stripes" is quite different from one who produces the same naming error but describes it as "a big, blond cat, referred to as the king of the jungle." The former presumably has a semantic impairment, whereas the latter may have difficulties in retrieving the appropriate lexical phonological form. In neither would a post-lexical locus seem to be implicated. As a consequence, a pattern of performance in which semantic errors are produced exclusively or primarily in spoken but not written output is one line of evidence that cannot readily be dismissed by proposing a post-lexical locus of the spoken errors. Given this, the reports of semantic errors in the spoken modality with largely correct or recognisable responses in the written modality constitute some of the strongest pieces of evidence to date in support of the autonomy of orthography in language production.

Few cases exhibiting this pattern have been well documented. One of them, RGB (Caramazza & Hillis, 1990), made frequent (25–30%) semantic errors in reading and in oral naming of pictures: p(kangaroo) → "giraffe," p(mittens) → "glove," p(thumb) → "wrist" (see also Basso et al., 1978; subject JSR in Hillis & Caramazza, 1995; and Nickels, 1992). However, RGB made no semantic errors in written naming or in writing to dictation, where errors consisted only of recognisable misspellings of the target word [p(celery) →

C-E-L-E-Y; p(kangaroo) → K-A-G-O-O]. In addition, he gave clear evidence of intact semantic knowledge of the misnamed items. Thus, although RGB orally named a p(leopard) as a "rhinoceros" he described it as "a kind of cat with spots." The intact comprehension of misnamed terms indicates that the locus of impairment must be post-semantic. The fact that semantic errors (rather than phonemically based errors) were produced makes a post-lexical locus of impairment unlikely. In fact, in order to entertain a post-lexical locus for the semantic errors one would have to argue something like the following: Although phonemic distortions are generated, the responses are aborted and subsequent attempts result in the production of correct or semantically related forms. However, the total absence of phonemic errors in RGB's performance in any task and the absence of an account for why semantic errors in particular should be produced (e.g. as opposed to "don't know" responses or phonologically similar word errors) render this line of reasoning vacuous. Consequently, the deficit responsible for the semantic errors in RGB's case has been attributed to the level at which lexical phonological representations are activated for output. Specifically, Caramazza and Hillis proposed that a semantic representation (e.g. [hairy-barking-domestic-young-animal]) serves as the basis for the activation of a set of lexical form representations to varying degrees depending upon the extent to which they match the semantic features of the target (e.g. "puppy," "dog," "cat," "fox," "seal"). The most active representation, normally the correct word, is then made available for output. However, if the target name is not available then the most highly activated member of the set will be produced, and a semantic error will result (e.g. PUPPY → cat).

Orthographic Access via Multiple Attempts at Phonological Retrieval

Although the evidence provided by cases such as RGB crucially avoids the concern about a post-lexical locus of impairment, it is, nonetheless, subject to a different type of objection. While granting that the semantic errors produced in speech result from difficulties encountered in the retrieval of lexical phonological forms[3], one might nonetheless be concerned that the absence of semantic errors in writing results simply from the opportunity afforded by the writing task to attempt to gain access to a phonological form repeatedly before producing a written response. According to this hypothesis of "phonological mediation + multiple retrieval attempts," semantic errors are not present in writing because the subject produces a written response only *when* the correct

[3] We make no claims that the deficit is one specifically affecting retrieval processes vs. stored forms. As indicated in Rapp and Caramazza (1993), this is not a straightforward distinction to make.

response becomes available phonologically (whether it is overtly produced or not). This objection gains further plausibility if we consider that in the reported cases written and spoken naming were apparently assessed on different occasions. It is possible that when subjects are in a writing task they may be more likely to make repeated attempts at phonological retrieval before producing a written response.

Given this concern, the hypothesis of phonological mediation should, ideally, be tested by having a subject concurrently say and write the names of objects. However, given the obvious problems with this procedure, we can approximate it by having an appropriate subject systematically produce the written and the spoken name of each item in close temporal proximity on each naming trial. If success in writing is necessarily mediated by successful phonological retrieval, then the subject should typically follow a correct written response with a correct spoken one, and an incorrect written response with an incorrect spoken one.

In sum, one critical type of evidence in the phonological mediation/orthographic autonomy debate would consist of: (1) a spoken deficit that can be localised to a level of lexical phonological representation and (2) correct written vs. incorrect spoken responses assessed *for the same items on the same trial*. The performance of the subject of this report, PW, fulfils both of these criteria.

PW was an individual with largely intact comprehension who produced semantic errors and "don't know" responses in both written and spoken naming. Critically, however, when tested on the same trial in both output modalities, PW was often consistently able to produce correct written responses in the face of persistent difficulties with spoken responding. In the Case Study section we establish a lexical locus of the spoken naming errors; in the Experimental Studies section we document the critical performance pattern. Additionally, we take up (and reject) the possibility that this pattern can be attributed to: (1) phonological instability or (2) partial activation of phonological representations.

CASE STUDY

In this section we first present a description of the subject and the results of background testing; we then go on to report results of production and comprehension tasks that allow us to establish the functional loci of his deficits in spoken and written production.

PW was a right-handed male who had completed one semester of college and was employed as a manager of a meat department when he suffered a left-hemisphere stroke (following oral surgery) at the age of 51 (2/1990). CT scanning revealed an ischaemic infarction of the left parietal and posterior frontal areas (see Fig. 2). The CVA resulted in language difficulties as well as right-sided hemiplegia. Although PW was forced to write with his left hand, he

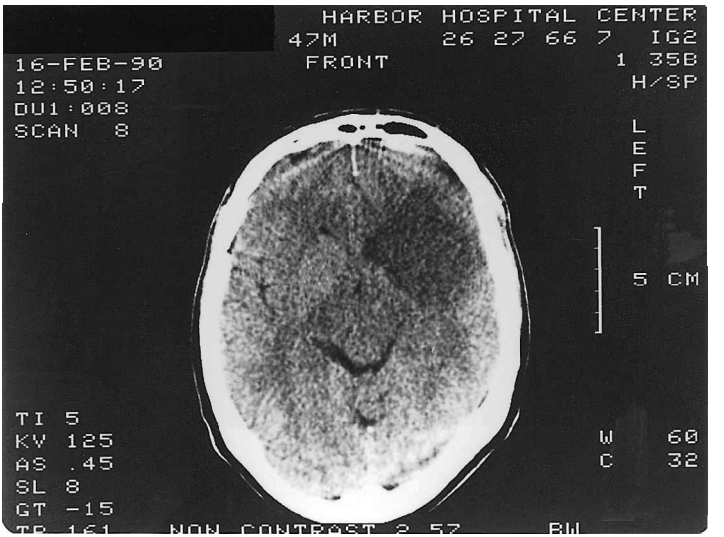

FIG. 2. CT scan for PW indicating left parietal and posterior frontal damage.

wrote quite easily and legibly. PW's visual fields were full and there was no sign of neglect. This investigation was carried out between 24 and 48 months after the CVA. PW's naming performance improved somewhat over this time period, although his pattern of errors remained virtually unchanged.

In our preliminary examination we noted that PW's speech was grammatically correct and that he exhibited no signs of phonemic or articulatory disturbance. In spontaneous speech we observed frequent hesitations due to word-finding difficulties, numerous circumlocutions, and semantic errors. In addition, he was able to generate only six animal names in 90sec. In contrast, he was able accurately to repeat words (90%), nonwords (100%), and sentences containing 5–8 words (100%). His ability to complete aurally presented sentences was also intact (100%). In terms of auditory sentence comprehension he was able to make sentence–picture matching judgements involving reversible sentences with 88% accuracy and grammaticality judgements with 80% accuracy.

In an assessment of his sublexical processing abilities, PW was given a set of 50 three- and five-letter nonwords for reading, repetition, and writing to dictation. PW repeated 92% of the nonwords correctly, with the occasional errors consisting of the production of phonologically similar words (/higl/ → "eagle"). In reading and writing to dictation, however, none of the

nonwords were produced correctly. However, if instead of considering whole-stimulus accuracy we evaluate his nonword performance by considering the accuracy of each letter (in writing) and each phoneme (in reading), his accuracy was 35% in writing and 61% in reading. Errors in writing nonwords consisted predominantly of similar nonwords (e.g. /fum/ → F-O-M or /dItl/ → D-I-X) that typically included correct first or second letters. In reading, errors consisted predominantly of similar word responses (e.g. BOT → "bottle"; TASIN → "tasty"), although other nonword errors were also produced (e.g. DOX → /dræk).

Single Word Production

In order better to understand the locus of his difficulties in spoken and written word production, we asked PW to carry out the following tasks with 258 items of the Snodgrass and Vanderwort (1979) picture set: spoken picture naming, written picture naming, reading, writing to dictation, repetition, and written name copying.

The results are presented in Table 1. Considering first the tasks involving spoken output, the results indicate that PW's spoken picture naming was marked by numerous semantic errors (19%), which were often accompanied by a verbal indication that he knew he had not produced the correct word [e.g. p(zebra) → "horse, not really (. . .) a horse in the jungle"]. Similarly, PW's "don't know" responses (6%) were also often accompanied by a description indicating that he was familiar with the item but could not come up with its name [e.g. p(thimble) → "I don't know the name, you put it over your finger and you sew"]. His overall spoken naming accuracy of 72% correct reveals a marked impairment with respect to that of elderly control subjects, for whom accuracy ranged from 91–100%.

TABLE 1
Percentage of Response Types on Various Tasks with the Same Stimuli ($N = 258$)

	Oral Pix Naming	*Reading*	*Repetition*	*Written Pix Naming*	*Writing to Dictation*	*Copying*
Correct	72.1	89.2	99.6	45.8	43.8	94.2
Semantic	19.0	2.3	0.0	12.4	8.1	0.0
Don't know	5.8	0.0	0.0	16.3	15.1	0.0
Similar nonword	0.0	0.8	0.0	10.9	9.7	5.8
Other nonword	0.0	0.8	0.0	5.8	9.3	0.0
Similar word	0.0	4.2	0.4	3.1	4.2	0.0
Other word	2.3	1.2	0.0	4.7	7.0	0.0
Other	0.8	1.6	0.0	1.2	2.7	0.0

In contrast to spoken naming, in reading PW produced only very few semantic errors (e.g. FISH → "horse") and he never produced a "don't know" response. PW's reading included a number of "similar word" responses (4%), which were responses sharing at least 50% of the target letters in the same relative order (e.g. SLED → "shed"), as well as various "other word" responses that did not meet this 50% similarity criterion (e.g. TOP → "tie"). The observed reduction in semantic error rate between picture naming and reading as well as the presence of mixed semantic/similar word errors [4/6 of the semantic errors produced in reading also met the criterion of similar word errors: p(cigar) → "cigarette"; p(shirt) → "shirt"] is consistent with the notion that, in reading, the opportunity exists for combining (inadequate) information generated by the lexical route with (inadequate) information from the sublexical orthography-to-phonology route. This summation of lexical and sublexical phonological information allows for a decrement in semantic error rates in reading vs. spoken naming (for further discussion of this summation hypothesis see Hillis & Caramazza, 1991, 1995). Because of this summation possibility, subsequent analyses directed at establishing the locus of the spoken and written naming deficits use only spoken and written naming data and do not include data from reading and writing to dictation.

As we had observed in our preliminary testing, Table 1 indicates that PW's repetition of words was practically flawless.

PW's performance was quite comparable in written naming and writing to dictation. In both we observe, as in spoken naming, a considerable proportion of semantic errors and "don't know" responses[4]. However, written production contrasts markedly with spoken naming in terms of the presence of a large number of similar word [e.g. p(stove) → S-T-O-R-K] and other word errors [e.g. p(stool) → S-O-C-K] as well as similar nonword [e.g. p(sandwich) → S-A-N-D-I-S-H] and other nonword errors [e.g. p(skunk) → S-Q-U-A-M]. The large number of similar nonword responses is an indication of post-lexical difficulties involving the graphemic buffer and/or letter form selection. We will return to this point later.

Finally, 6% errors were observed when PW was asked to copy written words directly. The errors were typically one-letter substitutions or deletions (e.g. HAND → H-A-N-b; PENCIL → p-e-N-I-L)). These errors may be indicative of a post-lexical deficit involving letter form selection; alternatively they may simply represent trials in which PW did not actually copy the stimuli but simply read them and then proceeded to retrieve the lexical orthographic forms as he would in a written naming task.

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[4] The reduction in semantic errors in writing to dictation (as compared to written naming) was accompanied by an increase in other word and nonword responses. Again, this pattern of semantic error reduction is consistent with the possibility of combining lexical and sublexical information in the task of writing to dictation.

Single Word Comprehension

The fact that PW often provided correct definitions of items he could not name or which resulted in a semantic error indicates that the primary source of semantic errors in written and spoken naming was not at the level of the lexical semantic system. However, in order to examine the possibility of semantic deficit more directly we used the same set of 258 Snodgrass and Vanderwort items in two comprehension tasks: (1) drawing items named by the examiner and (2) auditory yes/no word-picture verification.

In drawing, PW produced two errors (0.8% error rate) ("lamp" → picture of a rug; "key" → picture of a lamp). One of these can be classified as a semantic error. This error rate, although perhaps indicative of a slight semantic deficit, is certainly not comparable to the semantic error rates observed in spoken or written naming.

In the word–picture verification task, PW was shown each of the 258 pictures in the set on three different occasions accompanied either by the correct name, a semantically related word, or a phonologically related word. He was asked to indicate (yes/no) if picture and word matched. His accuracy on this task was 95%. The majority of his errors involved accepting a semantically related foil (e.g. chain for lock, grasshopper for beetle). This accuracy level was just slightly below the low end of the rates exhibited by normal elderly control subjects, whose accuracy ranged from 96% to 100%.

The Localisation of the Spoken Production Deficit/s

In order to consider the possible contribution of a post-lexical deficit to PW's spoken naming errors, we evaluated whether phonological length, phonemic complexity, and/or word frequency played a role in PW's spoken picture naming accuracy. As indicated earlier, it has been argued (e.g. Butterworth, 1992) that deficits affecting post-lexical processes involved in the buffering or elaboration of abstract phonological material may be especially sensitive to length and complexity and relatively insensitive to lexical frequency. Lexical deficits should show the reverse effects.

Phonological Length and Lexical Frequency

We submitted the results of PW's spoken picture naming to an analysis of variance to examine the relationship between accuracy, length, and lexical frequency[5]. Lexical frequencies were assigned to low, medium, or high categories according to the following frequency ranges from Carroll et al. (1971): lo = <5, mid = 5–60, hi = >60. The results for spoken naming were comparable

[5] Compound word stimuli were excluded from this and subsequent analyses of written naming errors due to obvious ambiguities in assigning length and frequency values.

TABLE 2
Results in Spoken Naming by Phoneme Length and Frequency
(6+ Phonemes Includes Words from 6–10 Phonemes)

	Low Freq.	*Mid Freq.*	*High Freq.*	*Totals*
2+3 phonemes	75%	82%	93%	86% (*N*=70)
4+5 phonemes	50%	73%	87%	70% (*N*=108)
6+ phonemes	57%	78%	–	70% (*N*=33)
Totals	55% (*N*=38)	76% (*N*=129)	91% (*N*=44)	

whether length was assessed in terms of number of syllables or phonemes, so we report results obtained with number of phonemes (see Table 2). The analyses indicate a significant effect of lexical frequency [$F(2,190) = 5.28$, $P < .006$], no significant effect of length [$F(8,190) = 1.21$, $P < .29$], and no interaction between the two [$F(10,190) = 0.55$, $P < .85$]

Relationship between Spoken Targets and Errors

Additionally, we considered whether the items that induced semantic errors were either longer or more complex than the semantic error responses that were produced. One might expect that if post-lexical phonological factors played any role in the PW's spoken errors, error responses might be phonologically simpler than targets. We found no evidence for this. Target words had, on average, 4.4 phonemes and .4 clusters while responses had an average of 4.5 phonemes and .4 clusters [$F(7,77) = 1.23$, $P<.31$; $F(2,77) = 1.25$, $P<.30$].

As indicated in the Introduction, it is crucial to establish a specifically lexical phonological locus for the spoken naming impairment if superior written vs. spoken naming is to be used as a strong argument against obligatory phonological mediation. In the case of PW we have quite effectively been able to rule out significant deficits to post-lexical components or the lexical semantic system and thus we conclude that the spoken deficit originates specifically at the level of phonological lexical form in production. To recapitulate, this conclusion is based on the following reasons: (1) good comprehension of misnamed items makes a primary lexical semantic deficit unlikely; (2) excellent repetition performance rules out a peripheral articulatory contribution; (3) the presence of semantic errors and "don't know" responses in the context of a complete absence of phonological errors in naming make a pre-articulatory/post lexical locus highly unlikely; (4) the absence of significant effects of factors such as phonological length and complexity further diminish the likelihood of pre-articulatory/post-lexical difficulties, and (5) the presence of a significant effect of lexical frequency is specifically predicted by a lexical level deficit.

The Localisation of the Written Production Deficit/s

Given PW's relatively intact comprehension, the primary source of written semantic errors presumably lies with difficulties in retrieving lexical orthographic forms. However, the numerous nonword errors and misspellings suggest an additional post-lexical deficit affecting the graphemic buffer. To provide confirmation of this characterisation of the writing deficits we examined the influence of word frequency and length on PW's written naming. As before, we submitted the results of PW's written naming to analyses of variance to examine the relationship between accuracy, length, and lexical frequency (see Table 3).

In contrast to the pattern observed for spoken naming, PW's written accuracy was significantly influenced both by number of letters [$F(9,188) = 4.74$, $P<.0001$] and (marginally) by lexical frequency [$F(2,188) = 2.93$, $P<.06$]; the interaction between the two was not significant [$F(11,188) = 0.35$, $P<.97$]. The frequency and length effects are predicted by lexical and graphemic buffer deficits respectively. On this basis we assume that both lexical level and post-lexical deficits affect written output.

EXPERIMENTAL STUDY

Predictions for Phonological Mediation/Orthographic Autonomy

To summarise, PW's performance on a number of lexical processing tasks reveals the following: (1) difficulties in spoken production that can be localised to the lexical level; (2) difficulties in written production that can also be localised to the lexical level; (3) an additional post-lexical disturbance affecting written production only; and (4) a possible slight semantic deficit. This case is

TABLE 3
Percent Correct in Written Naming by Letter Length and Frequency (7+ Letters Includes Words from 7–12 Letters in Length)

	Low Freq.	*Mid Freq.*	*High Freq.*	*Totals*
3+4 letters	71%	59%	82%	68% (*N*=80)
5+6 letters	33%	42%	69%	46% (*N*=88)
7+ letters	11%	24%	–	16% (*N*=43)
Totals	29% (*N*=38)	45% (*N*=129)	72% (*N*=44)	

different from a number of the others reviewed in the Introduction in that both spoken and written production were significantly affected. However, the fact that semantic errors and "don't know" responses were observed in *both* written and spoken naming can be interpreted in one of two ways: (1) under obligatory phonological mediation, the written errors must (at least in part) reflect the inadequacy of mediating phonological representations; (2) under orthographic autonomy the written errors represent an independent deficit to the orthographic output lexicon. One might expect that a case such as this one—involving deficits to both orthographic and phonological lexical representations—would not be ideal for observing correct written responses on the same trial as incorrect spoken responses. However, one should keep in mind that the presence of phonological and orthographic lexical deficits should simply reduce rather than eliminate the probability of observing this pattern. In fact, a situation in which both of the modality-specific lexical stores are affected provides a unique opportunity to evaluate additional predictions that follow specifically from the hypothesis of orthographic autonomy.

If access to orthographic and phonological lexical forms can occur independently, then when *both* modality-specific lexicons are damaged (as appears to be the case for PW) and when spoken and written naming are evaluated on the same trial, we would expect to observe the following: (1) the previously described critical pattern of correct responding in written picture naming and incorrect responding in spoken picture naming on at least some trials [p(pig) → "cow, no, cow, P-I-G, cow?, no!]; and *additionally*, (2) if we assume (as indicated in the Introduction) that a semantic representation activates a set of lexical form representations to varying degrees depending on the extent to which they match the semantic features of the target then, when the correct lexical form is unavailable in both of the modalities, we should expect to see different semantic errors in spoken vs. written output on the very same trial [p(knife) → S-P-O-O-N, "fork"]; (3) based on similar reasoning we should expect different "correct," roughly synonymous responses in the two output modalities [p(pig/hog) → P-I-G, "hog"]; and (4) when the phonological lexical form is available but the orthographic form is not, we should see the pattern of semantic errors in writing accompanied by correct spoken responses [p(lips) → N-A-I-L, "lips"].

We administered four tasks in order to determine if these response patterns could be observed when written and spoken naming were examined on the very same trial. As indicated earlier, multi-modality responding on the same trial should allow us to address the primary reservation regarding cases where semantic errors have been observed exclusively or primarily in the spoken modality. Specifically we should be able to address the concern that the absence of semantic errors in the writing of these individuals may have been due to the possibility that written responses were produced only after multiple (and eventually successful) phonological retrieval attempts.

Task 1: Written/Spoken naming

We asked PW to first write and then say the name of 256 black-and-white drawings of objects. PW was asked to look away as he wrote the object's name in order to eliminate the possibility that he would read his written response. This procedure was maintained throughout all of the subsequent tasks that we administered. On the few occasions when multiple responses were produced we scored the final written response and the first spoken one in order to examine the temporally most proximal responses. We first present overall response types for written and spoken naming (Table 4). We then go on to focus on the specific patterns of responding that are relevant to the orthographic autonomy/phonological mediation debate (Table 5).

In spoken naming PW produced 74% correct lexical choices; no phonemic errors were observed. In written naming 62% of PW's responses were correct lexical choices that were either spelled correctly or incorrectly. *Misspelled correct responses* were those nonword responses that contained more than 50% of the target letters in the correct relative order [e.g. p(church) → C-H-U-R-S-H; p(guitar) → G-U-A-R-T-I-A]. Similar rates of semantic errors were observed in both written and spoken naming (17% and 18% respectively). "Don't know" responses were produced at a rate of 13% in written naming and 7% in spoken naming. Additionally, neologisms and other word responses were observed almost exclusively in written naming. *Neologisms* were nonword responses sharing 50% or less of the target letters [p(rocket) → R-O-T-O-H]. *Other word* responses include all incorrect responses that are actual words of the language, regardless of their degree of overlap with the target [p(razor) → R-A-Y-O-N].

Critical Error Patterns

According to the hypothesis that written naming is based on phonological mediation + multiple retrieval attempts, the accuracy of the written response

TABLE 4
Distribution of Response Types for Task 1: Written and then Spoken Picture Naming on Each Trial (*N*= 256 Trials)

Response Type	*Written*	*Spoken*
Correct/misspelled	159(62%)	190 (74%)
Semantic/misspelled	43 (17%)	46 (18%)
No response	33 (13%)	19 (7%)
Neologism	10 (4%)	0
Other word	11 (4%)	1 (0.4%)
Total errors	97 (38%)	66 (26%)

signals the integrity of the phonological form that eventually mediated the written response. Thus we expect that correct spoken responses should typically be preceded on the same trial by correct written responses and, more importantly, that incorrect phonological responses should be preceded on the same trial by incorrect written responses. Critically we *do not* expect to find semantic errors and/or don't know responses in the spoken modality to be *preceded* by correct written responses.

This task should also allow us to observe the presence of those additional patterns of written and spoken naming that are clearly predicted by orthographic autonomy: different semantic errors in the two modalities, roughly synonymic responses in the two modalities, and correct spoken responses following semantic errors in writing.

Table 5 indicates that on 12 occasions PW's incorrect spoken responses were preceded by a correct [e.g. p(brush) → B-R-U-S-H + "comb"] or a recognisable written name [e.g. p(raccoon) → R-A-C-O-O-N-A + "sheep"]. In fact this critical pattern occurred on 12 of the 66 trials (Table 4) on which PW produced a spoken error. Additionally, as would be expected under orthographic autonomy, on 10 occasions PW produced different semantic errors in immediate succession in the 2 modalities [p(knife) → S-P-O-O-N + "fork"] as well as different "correct" responses in the 2 modalities (M-O-N-E-Y-S + "coins"; S-H-E-E-P + "lamb"). PW also produced 12 semantic errors in writing that were followed by a correct spoken response [p(lips) → N-A-I-L, "lips"].

TABLE 5
Number of Occurrences of the Critical Error Patterns for Task 1: Written and Then Spoken Picture Naming

Examples	*Write*		*Say*	*No.*
	CORRECT/MISSPELL		SEMANTIC	12
p(brush)→	B-R-U-S-H	+	"comb"	
	CORRECT/MISSPELL		NO RESPONSE	0
	SEMANTIC 1		SEMANTIC 2	10
p(thread)→	I-R-O-N	+	"thread"	
	CORRECT 1		CORRECT 2	2
p(sheep/lamb)→	*S-H-E-E-P*	+	"lamb"	
	SEMANTIC/MISSPELL		CORRECT	12
p(lips)→	N-A-I-L	+	"lips"	

Actual examples are included (*correct/misspell* refers to responses that were the correct lexical choice; they may or may not have been spelled correctly; *semantic/misspell* refers to responses that were semantic errors; they may or may not have been spelled correctly).

In an architecture involving obligatory phonological mediation, an individual with a lexical level phonological deficit should not be able to write correctly a name that he/she cannot say, yet this pattern of responding was apparently attested on 18% of the trials on which PW produced a spoken error. In addition, all other patterns specifically predicted under orthographic autonomy were observed. On the basis of these results it appears that correct written responding cannot be explained away simply as the result of the opportunity for increased attempts at phonological retrieval afforded by a writing task. These results are problematic for obligatory phonological mediation and yet are entirely consistent with orthographic autonomy.

Phonological Mediation + Instability

One might argue, however, that superior written vs. spoken naming results by chance from instability in the availability of phonological forms. Under such a phonological mediation + instability account, the trials in which superior orthographic vs. phonological responding is exhibited simply represent occasions on which the correct phonological representation is unavailable at the time of the overt spoken response, but happens to become accessible at a point in time when a (covert) phonological form is being used as the basis for generating a correct written response. Such an account would save the phonological mediation claim by arguing that the differences in spoken and written responding simply reflect changes in the availability of the appropriate lexical *phonological* representations: At one point in time a correct phonological representation is accessed and serves as the basis for the appropriate written response; at another point in time the representation is no longer available and a semantic error or "don't know" response is produced in spoken naming.

In order to examine if the discrepancies between PW's spoken and written responses were stable, we administered three additional tasks that required PW to produce multiple written and spoken responses on each trial. In Task 2 PW was asked to Write/Say/Write each item name, in Task 3 he was asked to Say/Write/Say the name of each item and, finally, Task 4 required PW to Say/Write/Say/Write/Say/Write the name of each picture. We first present results from these three tasks that relate to the critical response types. We then go on to present an analysis carried out specifically to assess the reliability of superior written vs. spoken responding.

Task 2: Written/Spoken/Written Naming

We presented PW with 33 pictures and asked him to write, say, and then again write the name of each picture.

The results presented in Table 6 indicate that PW did not produce the correct spoken form on 11 trials. Additionally, the results reveal a highly similar overall distribution of responses for first and second written responses. However, we

TABLE 6
Distribution of Response Types for Task 2: Written, Spoken, Written Picture Naming ($N = 44$ Trials)

Response Type	*Write*$_1$	*Say*$_1$	*Write*$_2$
Correct/misspelled	26 (59%)	33(75%)	27(61%)
Semantic	13 (30%)	6(14%)	13(30%)
No response	2 (5%)	5(11%)	1 (2%)
Neologism	1 (2%)	0	1 (2%)
Other word	2 (5%)	0	2 (5%)
Total errors	18 (41%)	11(25%)	17(39%)

TABLE 7
Number of Occurrences of the Critical Error Patterns for Task 2: Written then Spoken then Written Picture Naming on Each Trial

Examples	*Write*$_1$		*Say*$_1$		*Write*$_2$	*No.*
p(onion)→	CORRECT/MSP O-N-I-O-N	+	SEMANTIC "banana"	+	CORRECT/MSP O-N-I-O-N	1
p(pumpkin)→	CORRECT/MSP P-U-W-P-I-N	+	NO RESPONSE "don't know"	+	CORRECT/MSP P-U-M-P-I-N	3
p(table)→	SEMANTIC 1 D-E-N	+	SEMANTIC 2 "table"	+	SEMANTIC 1 D-E-N	1
	CORRECT 1		CORRECT 2		CORRECT 1	0
p(tongue)→	SEMANTIC T-E-E-T-H	+	CORRECT "tongue"	+	SEMANTIC T-E-E-T-H	7

Msp = misspell.

were specifically interested in determining if incorrect spoken responses could be preceded and followed by appropriate written responses. It was also important to determine if the three other patterns of responding predicted under orthographic autonomy would be reliably observed.

Table 7 indicates that there were four trials involving consistently superior written vs. spoken responding [e.g. p(onion) → O-N-I-O-N + "banana" + O-N-I-O-N]; three of these involved "don't know" responses in spoken naming and one involved a spoken semantic error. Thus, PW was consistently able to produce a correct written response on 4 of the 11 trials (36%) on which he produced a spoken error. With respect to the additional error types expected under orthographic autonomy: On one occasion a different semantic error was produced in the two modalities and on seven occasions semantic errors in writing were followed by correct spoken responses and again by the same

TABLE 8
Distribution of Response Types for Task 3: Spoken, Written, Spoken Picture Naming (N = 368 Trials)

Response Type	*Say*$_1$	*Write*$_1$	*Say*$_2$
Correct/misspelled	292(79%)	239(65%)	298(81%)
Semantic	27 (7%)	51(14%)	25 (7%)
No response	49(13%)	40(11%)	45(12%)
Neologism	0	21 (6%)	0
Other word	0	17 (5%)	0
Total errors	76(21%)	129(35%)	70(19%)

TABLE 9
Number of Occurrences of the Critical Error Patterns for Task 3: Spoken then Written then Spoken Picture Naming on Each Trial

Examples	*Say*$_1$		*Write*$_1$		*Say2*	*No.*
p(tiger)→	SEMANTIC "lion"	+	CORRECT/MSP T-I-G-E-R	+	SEMANTIC "lion"	2
p(bagel)→	NO RESPONSE "don't know"	+	CORRECT/MSP B-A-G-E-L	+	NO RESPONSE "don't know"	11
p(barrel)→	SEMANTIC 1 "bucket"	+	SEMANTIC 2 H-A-M-M-E-R	+	SEMANTIC 1 "bucket"	4
p(octopus/squid)→	CORRECT 1 "octopus"	+	CORRECT 2 S-Q-U-I-D	+	CORRECT 1 "octopus"	3
p(elbow)→	CORRECT "elbow"	+	SEMANTIC K-N-E-E	+	CORRECT "elbow"	20

Msp = misspell.

semantic error in writing [e.g. p(tongue) → T-E-E-T-H + "tongue" + T-E-E-T-H].

Task 3: Spoken/Written/Spoken Naming

With Task 3 we attempted to assess the possibility of correct orthographic responding in the context of *persistent* difficulties in spoken production: –Say$_1$/ + Write$_1$/–Say^2. We presented PW with 368 picture trials and asked him to say, write, and then again attempt to say, the name of each picture.

The distribution of overall response types is quite similar for first and second spoken naming trials (Table 8). Spoken errors were observed on 76 of the initial spoken responses. Importantly, Table 9 indicates that the pattern of good written naming in the face of persistent difficulties in spoken naming was observed on 13 of these 76 trials [e.g. p(tiger) → "lion" + T-I-G-E-R + "lion"; p(bagel) → "don't know" + B-A-G-E-L + "don't know"]. Additionally, on four trials different semantic errors were produced in the two modalities [p(tweez-

ers) → "pliers" + N-E-E-D-L-E + "pliers"] and on three occasions different correct responses were produced ["hog" + P-I-G + "hog"]. Finally, semantic errors in writing were preceded and followed by correct spoken responses on 20 trials [p(spool) → "spool" + N-E-E-D-L-E + "spool"]

Task 4: Spoken/Written/Spoken/Written/ Spoken/Written Naming

In order to push yet further at the possibility of appropriate written naming in the face of persistent errors in spoken naming, on each trial we asked PW to attempt to: say, write, say, write, say, and then write the name of each of 300 pictures. Recall that in our testing procedure PW is not permitted to look at the written responses until the entire trial is completed.

The overall distribution of response types are reported in Table 10. There were 38 trials involving an initial spoken error. In Table 11 we report the number of occurrences of the critical error patterns. We can see that, of the 38 trials involving an initial spoken error, there were 7 trials (18%) where an incorrect spoken response alternated with an appropriate written response throughout the course of the entire trial ($-Say_1/ + Write_1/-Say_2/ + Write_2/ - Say_3/ + Write_3$) [e.g. p(owl) → "turtle" O-W-L "turtle" O-W-L turtle O-W-L]. That is, although PW was consistently able to write the name of a pictured object, he was then repeatedly unable to produce the correct spoken form. Instead he systematically produced either a spoken semantic error (5/7) or a "don't know" response (2/7).

In addition, the other response patterns predicted by orthographic autonomy were also observed. There were 4 trials in which different semantic errors were consistently produced within each modality [e.g. p(hanging) → "throwing" T-O-U-C-H "hanging" T-O-U-C-H, etc.], 1 trial in which different correct responses were produced and 22 trials on which a correct spoken response was consistently followed by a semantic error in writing [e.g. p(shower) → "shower" T-O-I-L-E-T, etc.].

TABLE 10
Distribution of Response Types for Task 4: Spoken, Written, Spoken, Written, Spoken, Written Picture Naming (N = 299 trials)

Response Type	*Say_1*	*$Write_1$*	*Say_2*	*$Write_2$*	*Say_3*	*$Write_3$*
Correct/Msp	256(86%)	206(69%)	256(86%)	207(69%)	257(86%)	207(69%)
Semantic	21 (7%)	37(12%)	20 (7%)	32(11%)	18 (6%)	32(11%)
No response	17 (6%)	20 (7%)	18 (6%)	23 (8%)	19 (6%)	24 (8%)
Neologism	0	10 (3%)	0	12 (4%)	0	11 (4%)
Other word	0	26 (9%)	0	26 (9%)	0	26 (9%)
Total errors	38(14%)	93(31%)	38(14%)	93(31%)	37(14%)	93(31%)

Msp = misspell.

TABLE 11
Number of Occurrences of the Critical Error Patterns for Task 4: Spoken, Written, Spoken, Written, Spoken, Written Picture Naming on Each Trial

Examples	*Say*$_1$	*Write*$_1$	*Say*$_2$	*Write*$_2$	*Say*$_3$	*Write*$_3$	*No.*
p(owl)→	SEMANTIC “turtle”	CORR/MSP O-W-L	SEMANTIC “turtle”	CORR/MSP O-W-L	SEMANTIC “turtle”	CORR/MSP O-W-L	5
p(grapes)→	NO RESP “don't know”	CORR/MSP G-R-A-P-E	NO RESP “don't know”	CORR/MSP G-R-A-P-E	NO RESP “don't know”	CORR/MSP G-R-A-P-E	2
p(blouse)→	SEM 1 “sweater”	SEM 2 S-T-I-R-K	SEM 1 “sweater”	SEM 2 S-T-I-R-K	SEM 1 “sweater”	SEM 2 S-T-I-R-K	4
p(pillow)→	CORRECT “pillow”	SEMANTIC B-E-D	CORRECT “pillow”	SEMANTIC B-E-D	CORRECT “pillow”	SEMANTIC B-E-D	21
p(diaper)→	CORR 1 *“Pampers”*	CORR 2 D-I-A-P-A-M	CORR 1 “Pampers”	CORR 2 D-I-A-P-A-M	CORR 1 “Pampers”	CORR 2 D-I-A-P-A-M	1

Corr = correct; Msp = misspell; Sem = semantic; Corr = correct.

Evaluation of the Phonological Mediation + Instability Hypothesis

The results of Tasks 2–4 indicate that PW often consistently produced the correct lexical item in writing in the face of persistent failure in producing its spoken form. Of course, under the phonological mediation + instability hypothesis some number of such trials might be expected by chance. In order to evaluate whether the observed consistency is greater than that expected by chance, we must also take into account how many *in*consistent sequences were produced.

Under the phonological mediation + instability hypothesis, if the accuracy of a written response depends on the availability of the appropriate phonological form and, furthermore, if this availability changes over time, then the observation of a correct written response should not be specifically predictive of the accuracy of subsequent written responses on that trial. That is, subsequent responses—written or spoken—on a given trial will be correct or incorrect depending on the stability of the *phonological* form; accuracy should not be systematically related to output modality. Specifically, the expectation for those critical trials initiated by an incorrect spoken response and correct written response (–Say_1/ + Write_1) is that the accuracy of subsequent spoken and written responses should be comparable. Or, because of additional problems in the orthography, for subsequent within-trial responses *spoken accuracy should be superior to, but certainly no less than, written accuracy*. The hypothesis of orthographic autonomy makes a contrasting prediction: The pattern of superior written vs. spoken responding at the beginning of a trial is a reflection of the integrity of independent underlying phonological and orthographic forms and therefore under orthographic autonomy the prediction is that on –Say_1/ + Write_1 trials, subsequent within-trial responses should *show consistently superior* written vs. spoken responding.

Written vs. Spoken Responding

In order to evaluate these contrasting predictions, we considered all of those trials in Tasks 2, 3, and 4 that began with the critical –Say_1/ + Write_1 response pattern. If it is true that the observed superiority of written responding on these trials resulted from the chance availability of the correct (covert) phonological form, then on each trial subsequent spoken responses (Say_2 in Expt. 3; Say_2 and Say_3 in Expt. 4) should be correct no less often than the subsequent written ones (Write_2 in Expt. 2; Write_2 and Write_3 in Expt. 4).

In Task 2 there were a total of 4 trials starting with + Write_1/–Say_1; in Task 3 there were 16 trials beginning with –Say_1 + Write_1; in Task 4 there were a total of 9 trials initiated by correct written and incorrect spoken responding. Table 12 reports the accuracy of subsequent written and spoken responses on these critical trials. The results indicate that on trials initiated with a correct

TABLE 12
Accuracy of Subsequent Written and Spoken Responses on Trials Initiated with a Correct Written and Incorrect Spoken Response

	$-Say_1/+Write_1$ (N)	$+ Write_{2,3}$	$+ Say_{2,3}$
Task 2	4	100% (4/4)	–
Task 3	16	–	19%(3/16)
Task 4	9	100%(18/18)	22%(4/18)
Totals	29	100%(22/22)	21%(7/34)

written and an incorrect spoken sequence, 100% (22/22) of subsequent written responses were correct lexical choices, but only 21% (7/34) of the subsequent spoken responses were correct [$\chi^2(1,53) = 28.6$, $P<.001$). Yet, as indicated earlier, if superior written vs. spoken responses result simply from changes in the availability of phonological forms, then the initial responses should not predict that subsequent written ($Write_{2,3}$) should be any more accurate than subsequent spoken ($Say_{2,3}$) ones. These results reveal strong within-modality consistency and clearly render untenable the possibility that superior written vs. spoken responding may have resulted merely from phonological mediation via inconsistently available phonological forms.

Summary of Experimental Results

Across the four experimental tasks PW was administered 958 picture trials for written and spoken naming, involving a total of 3488 responses. Of these picture naming trials, 20% (191/958) involved initial spoken errors—nearly half of these were semantic errors and the rest were "don't know" responses. In terms of the issues that these tasks were designed to address, the results indicate that on 19% of trials involving spoken errors (36/191), PW consistently produced an appropriate written response. That is, in spite of considerable damage to the orthographic lexicon, PW was able to produce the appropriate lexical orthographic form on one out of five occasions on which he was unable to produce the appropriate spoken form. Furthermore, we have shown that this response pattern cannot be attributed to instability in the availability of correct phonological forms. In addition, all other error patterns expected under the orthographic autonomy hypothesis were observed: 19 of the 100 trials involving semantic errors in spoken naming involved the consistent production of a different semantic error in written production; on 6 trials, correct but different synonymic responses were produced in the two modalities, and 61 trials involved a correct spoken response accompanied by a semantic error in writing.

The evidence that is problematic for obligatory phonological mediation seems to be clear and overwhelming: Consistently appropriate written responses can be produced in the context of the persistent inability to produce the spoken form. We now make one further attempt to salvage the hypothesis of obligatory phonological mediation.

Phonological Mediation via Impoverished Phonological Material

An alternative interpretation of the data that would preserve an architecture of obligatory phonological mediation might be suggested by the fact that the subjects previously reported with a pattern of semantic errors restricted to the spoken modality typically produce written responses containing orthographic distortions: p(thumb) → T-__-M-B, p(envelope) → E-N-V-O-L-E-P-E, p(banana) → B-A-N-A-S-H-A (Caramazza & Hillis, 1990; Nickels, 1992). For example, RGB produced these written errors at a rate of 80% and approximately 90% of HW's written responses contained spelling errors (Caramazza & Hillis, 1990). This raises the possibility that *impoverished, partial* phonological representations of target items *are* retrieved and, in fact, serve as the basis for orthographic retrieval. According to this account, it is the inadequacy of the phonological representations that results in the orthographic distortions. The difference between phonological and orthographic response types (semantic errors vs. misspellings) is due to the fact that, although there are no restrictions on the production of orthographically distorted forms, phonological distortions may be such that they cannot be articulated. In those cases the subject may provide a circumlocution, a "don't know" response or, when another related and intact phonological representation is available, a semantic error[6]. In this way, this hypothesis would allow one to maintain phonological mediation, albeit via "inadequate" phonological material. Recall that under orthographic autonomy the misspellings arise from a post-lexical locus such as the graphemic buffer.

The possibility that distorted, partial lexical phonological forms underlie PW's appropriate written responses can be rejected for two reasons. First, this scenario is improbable in light of the absence of any evidence of phonological distortions in PW's spoken production as well as the finding that phonological variables (length, complexity) do not contribute to his spoken error rates. One would have to argue that the distortion of phonological lexical forms never manifests itself except through errors in writing. Clearly, this is not only ad hoc but also irrefutable. Second, we can examine spelling accuracy on +Write/–Say

[6] The orthographic responses need not be faithful reflections of the available phonological material. That is, it is not necessarily the case that the fact that D-O-K-E-Y is produced means that the mediating phonological material consisted of /douki/.

trials where, until now, we have grouped together both correctly spelled and misspelled correct lexical choices. When we do so, we find (across the four tasks) that written responses on the critical + Write/–Say trials were correctly spelled fully 61% of the time. Thus, it is simply not the case that the pattern of superior written vs. spoken responding occurs only in the context of misspellings. Both of these reasons make it difficult to sustain a hypothesis of obligatory phonological mediation via impoverished phonological material.

DISCUSSION

We have described the performance of an individual who is often unable to produce the correct spoken name of an item although he is able to produce its written name. We have shown that this individual demonstrates the two critical features that are necessary for such a performance pattern to be used as evidence against obligatory phonological mediation: (1) the deficit in spoken production can be characterised as one affecting the retrieval of lexical phonological forms and (2) a pattern of consistently superior written vs. spoken naming is observed for the same items on the very same trials. Given that under the obligatory phonological mediation hypothesis this conjunction of events should never occur, the hypothesis would seem to be invalidated. We have specifically considered and rejected the possibility that these results could be attributed either to the instability of phonological representations or to phonological mediation via impoverished phonological representations. We now consider the issue of optional phonological mediation (see Miceli, Benvegnù, Capasso, & Caramazza, this issue, for additional discussion).

As we indicated in the Introduction, our goal with this study was to examine the hypothesis of *obligatory* phonological mediation—the claim that orthographic lexical forms *cannot* be retrieved without prior access to their corresponding phonological lexical forms. With the earlier discussion we hope to have dealt with possible remaining concerns regarding the strength of the relevant evidence. We have argued that the findings presented here convincingly deal with the inadequacies in the previously existing results and that they demonstrate that orthographic lexical forms can indeed be retrieved without prior access to the corresponding lexical phonological representations. We can also ask if *optional* phonological mediation occurs in written language production.

The evidence that points to the possibility of optional phonological mediation in production is basically of two types. First, there is the strong subjective experience that most people report of "hearing" themselves while they are writing. Second, certain classes of written errors that normal, unimpaired subjects produce seem to have a phonological basis—writing HERE for HEAR, for example. We shall briefly consider each of these in turn.

The subjective experience of listening to oneself as one is writing can be interpreted in at least two ways. One possibility is that, indeed, in those situations we are engaging in phonologically mediated writing. The second is that the covert production of spoken forms plays no causal role in orthographic retrieval but is simply a *concomitant* process. That is, having generated a message to be communicated and having selected the corresponding lexical semantic items to be used in expressing the message, we then proceed—as a matter of course, albeit unnecessarily—to retrieve both written *and* spoken forms. A similar point can be made with respect to the subjective experience of hearing words as we read. It does not imply that we *must* retrieve the phonological form before we are able to understand the meaning of the printed stimulus; it may simply be that we *also* retrieve the phonological form in the course of processing the written item. Thus, although the subjective experience is compelling it certainly does not require that we posit phonological mediation. In this regard, it is interesting that the individual described by Levine et al. (1982) (see also Martin et al., 1995) was described as lacking the experience of inner speech, yet he was able to write coherent sentences and paragraphs.

A stronger case can be made for optional phonological mediation from evidence provided from normal writing errors—slips of the pen. The error type that most clearly points to the role of phonology in orthographic retrieval are homophone substitutions—writing HEAR for HERE, SEEN for SCENE, YOUR for YOU'RE—and, to a lesser extent, structurally similar word substitutions—SURGE for SEARCH, A NUMBER for ANOTHER, COULD for GOOD. Hotopf (1983) attempts to determine if the basis for these substitutions is phonemic or orthographic. He does so by calculating the extent to which the written homophone and similar word substitutions share phonemes and graphemes with the intended target words. He then compares this with the proportion of graphemes and phonemes shared between targets and errors in *spoken* slips. As Hotopf himself indicates, the results are not definitive. Although for spoken and written slips involving open-class items, target words and errors share, on average, a slightly greater number of phonemes than graphemes, the effect is reversed for closed-class items. Furthermore, a consideration of the individual errors in all categories indicates many instances in which targets and errors share greater numbers of graphemes than phonemes. The difficulty in using this type of analysis derives from the large degree of overlap between phonological and orthographic units—words that are phonologically similar will also be orthographically similar and vice versa.

However, even if the analysis of slips of the pen had clearly shown their phonological origin, the results would still be open to a number of interpretations. The first possibility, of course, is that these errors reflect optional phonological mediation. A second possibility is that the errors result from connections made between semantics and orthography in the course of learning. If, for example, in learning there was confusion in establishing HEAR vs.

HERE as the appropriate orthographic form for the meaning [listen] then, to the extent to which those associations remain in adulthood, they may serve as the source of occasional error. A third possibility is that the homophone and structurally similar word confusions are the consequence of concomitant phonological processes. This alternative depends on the following: (1) phonological forms are (often or even typically) retrieved in the course of writing and (2) when these phonological forms are subjectively "heard" they do, in fact, engage a number of the mechanisms dedicated to auditory comprehension. In that case, /hir/ may be retrieved when the semantics of /listen/ is activated in the course of preparing a written message. Given that auditory comprehension mechanisms use phonological information to access the phonological lexicon, we expect /hir/ to activate any identical, and, presumably, similar lexical entries. Thus, lexical entries for "hear" and "here" should both receive activation. The activation of these lexical entries may, in turn, result in the passing on of activation through semantics and on to the orthographic lexicon. When that occurs there may be occasions where both H-E-A-R and H-E-R-E are active when the time comes to retrieve the written form. Occasional confusions would not then be surprising. This scenario is especially plausible if we consider that written production processes are considerably slower than speech processes (Hotopf, 1980).

In sum, none of the available evidence requires that we adopt optional phonological mediation in written language production. However, the possibility of optional phonological mediation is an important one that merits, and presumably is amenable to, further empirical scrutiny. If it turns out that both autonomous orthographic retrieval and optional phonological mediation are possible, we need to consider the following questions: With what frequency and under what circumstances are these two options employed? Does optional phonological mediation occur via direct lexical–lexical connections (Fig. 1c) or via sublexical connections (Fig. 1d)?

This paper focuses specifically on the question of *obligatory* phonological mediation. In this context, we have been able to: (1) document a pattern of consistently correct written responding in the face of persistently incorrect spoken production; (2) we have considered and rejected a number of alternative interpretations of this pattern that would allow us to retain obligatory phonological mediation; and finally (3) we have reported the full range of error patterns expected under orthographic autonomy. On this basis we conclude that orthographic lexical forms can indeed be independently accessed for production without an obligatory mediating role for phonology.

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