

## Cognitive Analysis of a Case of Pure Dysgraphia

GABRIELE MICELI AND M. CATERINA SILVERI

*Università Cattolica and Istituto di Psicologia, CNR, Rome, Italy*

AND

ALFONSO CARAMAZZA

*The Johns Hopkins University*

An Italian patient with a pure dysgraphia who incorrectly spelled words and nonwords is described. The spelling errors made by the patient were not affected by lexical factors (e.g., frequency, form class) and were qualitatively the same for words and nonwords. The pattern of writing performance is discussed in relation to current models of writing and, specifically, in relation to the role of the Output Grapheme Buffer and Phoneme-Grapheme Conversion in writing.

© 1985 Academic Press, Inc.

Over the past decade we have witnessed a sustained effort to understand the nature of the reading mechanisms that are disrupted in various forms of acquired dyslexia. This effort has led, on the one hand, to a rich typology of acquired dyslexia and, on the other hand, to the development of richly articulated models of the reading process (Shallice, 1981a, 1981b).

The mosaic of reading deficits that has been described has strongly influenced notions of the organization and functioning of the lexicon as well as the structure and functioning of nonlexical mechanisms implicated in the reading process. Thus, for example, the pattern of reading errors that characterize deep dyslexia (see Coltheart, Patterson, & Marshall, 1980) clearly suggests an organization of the lexicon that honors a distinction between root morphemes and grammatical markers, both affixes and free standing grammatical morphemes (Caramazza & Berndt, in press). Furthermore, the contrast in reading deficits observed in phonological and

The research reported in this paper was supported in part by a grant from the CNR and by NIH Grant 14099 to The Johns Hopkins University. Address reprint requests to Gabriele Miceli, M.D., Servizio di Neuropsicologia, Università Cattolica, Largo A. Gemelli, 8, 00168 Rome, Italy.

surface dyslexia has been interpreted as suggesting the existence of a nonlexical reading mechanism that converts graphemic sequences into phonological patterns without the mediation of the lexicon (Coltheart, 1981; but, see Marcel, 1980, for an alternative account).

While writing disorders have not received the concerted attention that has been devoted to reading disorders, there is substantial literature on the relation of dysgraphia to other language processing disorders (see Marcie & Hecaen, 1979, for a review), and in the last several years a number of investigators have reported detailed analyses of patterns of dysgraphia. Already a number of published reports have described forms of dysgraphia that correspond in relatively clear fashion to different forms of dyslexia. Cases of deep (Bub & Kertesz, 1982; Nolan & Caramazza, 1983), surface (Beauvois & Dérouesné, 1981), and phonological dysgraphia (Shallice, 1981b), which parallel homologous types of reading disturbances, have been reported. The patterns of dysgraphia reported have been used to formulate some of the major features of the writing process. Thus, by a logic similar to that used in the interpretation of the dyslexias, the distinction between phonological (patients who can write words but not nonwords) and surface dysgraphia (patients who can write nonwords and regularly spelled words but not irregularly spelled words) can be used to motivate the postulation of a dual writing route. The existence of patients with selective deficits either in writing nonwords or irregularly spelled words suggests a distinction between impairments to a "phonological" route and to a "lexical" route, respectively. Similarly, the existence of semantic paragraphic errors (e.g., writing TRIAL for SENTENCE or FIGHT for ARGUMENT; see Bub & Kertesz, 1982; Nolan & Caramazza, 1983) in writing to dictation has been taken to reflect the functioning of an independent lexical writing route when the Phoneme-Grapheme Conversion system is disrupted.

The postulation of a separate lexical route in writing is not only supported by the empirical facts we have reviewed but, as Ellis (1982) has so cogently argued, there is a *prima facie*, compelling argument that can be made for a direct graphemic route in writing English. The relationship between pronunciation and orthography in English is relatively opaque (as is that of French and many other languages); the spelling of most English words (e.g., *gate*, *gait*) although regularly related to their pronunciation cannot be determined exclusively from the pronunciation (/wet/ → *wait* and not *wate*, but /ret/ → *rate* and not *rait*), and many words have a very indirect relationship between their orthographic and phonological structure (e.g., /so/ → *sew*). Clearly, writing in English strongly implicates the direct access of orthographic information from the lexicon. Accordingly, the models of writing that have been proposed recently have assumed that writing words involves the selection of orthographic entries in the output lexicon which are placed in a Graphemic Buffer

while subsequent, lower lever writing processes are executed (e.g., Morton, 1980). Writing nonwords does not involve the lexical system in these models; phonological representations are converted into graphemic forms by a Phoneme–Grapheme Conversion system and placed in the Graphemic Buffer for subsequent processing.

There are several interesting issues that arise from the adoption of a dual route model of writing. One issue concerns the way in which such models account for spelling errors in different forms of dysgraphia. While the models can explain phonologically related spelling errors (e.g., *rait* for *rate*)—indeed the models were motivated in part by the occurrence of such spelling errors—it is not clear how visually related spelling errors [(e.g., *stilts* → *stile*, *globe* → *glove* from patient J.S. (Caramazza, Berndt, & Basili, 1983); *lion* → *lorn*, *mountain* → *mouction* from patient A.F. (Hier & Mohr, 1977); *tractor* → *tracton*, *language* → *languate*, from patient V.S. (Nolan & Caramazza, 1983)] can be explained within such models. At what level(s) are we to locate the “lesion(s)” to explain this type of deficit?

A second issue to be considered concerns the degree of independence between the two routes and whether the phonological representation of a word plays any role in writing. Some authors have argued for the complete independence of the two routes (Shallice, 1981b; Bub & Kertesz, 1982; Ellis, 1982) while others have proposed the possibility that the two systems may interact in normal writing (Nolan & Caramazza, 1983).

Finally, we will want to consider whether the dual route architecture of the writing process is an intrinsic property of the human cognitive system or whether it is a language-specific property. Unlike languages like English and French where the Phoneme–Grapheme Conversion system can, at best, play only an indirect role in writing words the situation could be quite different in a language like Italian. The relationship between pronunciation and orthography in Italian is perfectly transparent—there is a one to one relationship between orthography and pronunciation. Writing in a language like Italian can be accomplished without loss of accuracy through a Phoneme–Grapheme Conversion system. It is entirely possible, therefore, that the role of a Phoneme–Grapheme Conversion system in two languages like Italian and English is quite different. In Italian, because of the transparency of its orthography, there could be a much more extensive or even exclusive reliance on the Phoneme–Grapheme Conversion system in writing.

In this report we consider these issues in light of a detailed analysis of the writing performance of an Italian patient with pure dysgraphia.

### CASE HISTORY

F.V. was a 60-year-old lawyer when he suffered a cardiovascular accident in November 1982. In the early stages he presented with a mild aphasia

characterized by the presence of phonemic substitutions in speech production, naming, and repetition, but with very good comprehension. The patient also showed a disproportionately severe writing disorder.

The patient made a very rapid recovery, and his aphasia cleared progressively, to the extent that he resumed his practice. However, the writing disturbance persisted and the patient was seen at the Neuropsychology Service of the Catholic University of Rome for a detailed neuropsychological examination.

#### Neurological Exam

F.V. was seen for the first time 45 days after the stroke. Physical examination was normal. No motor weakness or visual field defect could be detected on careful clinical evaluation. The patient's only physical complaint was numbness in his right hand.

A CT scan was performed. A very small lesion was shown involving the uppermost portion of the angular gyrus and perhaps the lowermost portion of the superior parietal lobule with very minor involvement of the subcortical white matter (Fig. 1).

#### Neuropsychological Exam

F.V. was tested as an outpatient over a 2-month period. During this period his writing deficit remained highly stable.

On a standard neuropsychological evaluation, no aphasic signs could be detected. Spontaneous speech was fluent, with good articulation, a

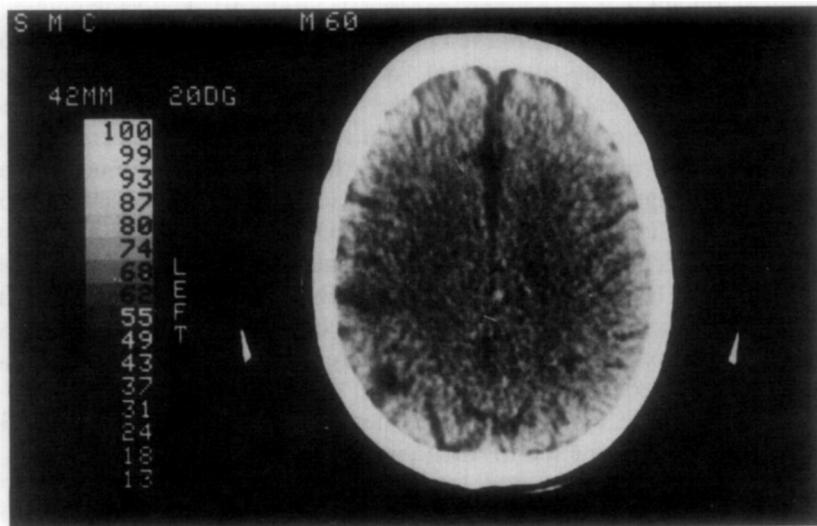


FIG. 1. CT-scan sections showing a small area of hypodensity in the superior parietal lobule.

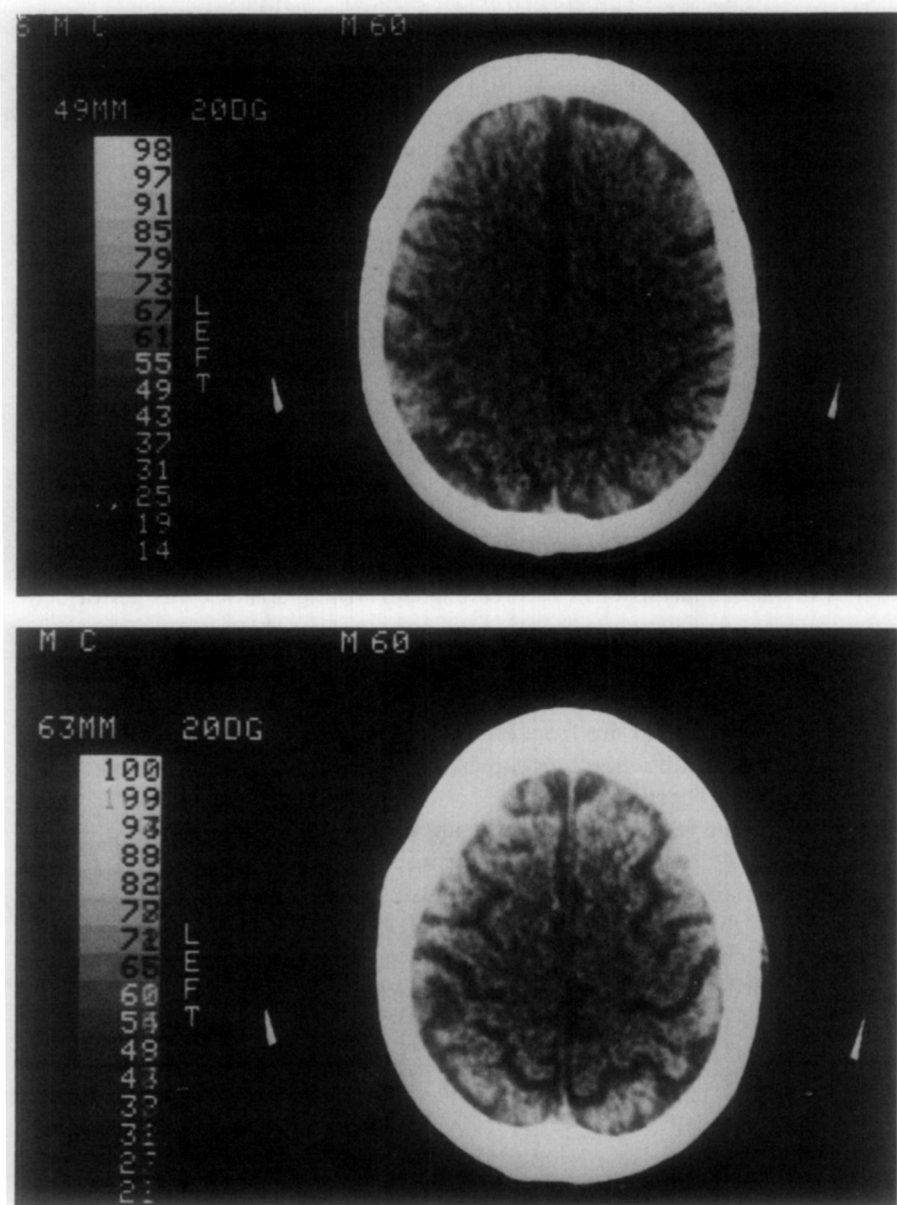


FIG. 1—Continued.

very rich vocabulary, and a fully normal variety of syntactic constructions. Paraphasias were absent. Repetition was flawless for words, nonwords, and sentences with a large variety of grammatical constructions. On the Boston Naming Test (Kaplan & Goodglass, 1976), all 85 items were named promptly and correctly. In other language tests the following

results were obtained: (1) discrimination and labeling of CCVC syllables with stop consonants in the initial position were well within normal limits (95.5% correct on discrimination; 94.2% correct on labeling); (2) word-picture matching performance was perfect for both aurally and visually presented words; and (3) comprehension of sentences (active reversible, passive reversible, temporal relations before/after, embedded active, embedded passive) was performed at a 95% level of accuracy, within normal limits for F.V.'s age and education. On a shortened version of the Token Test (De Renzi & Faglioni, 1978) the score was 35/36.

On tests of general intelligence, F.V.'s performance was also within the upper range of normality (WAIS: total IQ: 119, verbal IQ: 119, performance IQ: 117, Wechsler Memory Scale: 132).

No signs of buccofacial, limb, or trunk apraxia were found. Right-left orientation, autotopagnosia, constructional abilities, and calculations were normal. The patient did present, however, with a very mild tactile-agnosia, but no signs of digital agnosia. F.V. could name 12/12 common objects presented tactually in his left hand, but only 10/12 common objects put in his right hand, suggesting a mild tactile agnosia.

A detailed analysis of F.V.'s reading and writing abilities was performed.

## EXPERIMENTAL TASKS

### Reading

Reading disorders are frequently associated with dysgraphia, and their presence may influence writing (Ellis, 1982). F.V.'s reading ability was therefore, explored carefully.

The patient read a narrative of approximately 200 words at a normal speed and without errors. Furthermore, his performance on a reading test comprising 220 words and 100 nonwords was entirely normal. The word stimuli in this latter test were selected so as to control relevant variables (length, frequency, word class, abstractness). F.V. read correctly all the words and 99/100 nonwords (including two spontaneous self corrections). F.V.'s reading ability is clearly unimpaired.

### Writing Tests

#### *a. Spontaneous Narrative*

F.V. gave a 121-word rendition of the Little Red Riding Hood story (see Appendix I). He wrote easily and fluently. A sample of his handwriting is shown in Fig. 2. F.V.'s writing was fully grammatical and had a normal range of word choice. However, his writing was marred by frequent spelling errors (32 errors—26.4%). Errors occurred on words of all grammatical classes, and especially on longer words. Errors consisted of substitutions (e.g., *portafoglio* → *portofoglio*), additions (e.g., *elica* → *eclica*), deletions (e.g., *unicorno* → *unicono*), or transpositions (e.g.,

Caffaretto rosso  
 È una famiglia che ha introvato sopra ~~un~~  
 un merco le magnus le le convegiuato  
 un mastello rosso, che la fuma, intonda  
 anche oggi che è in morte della nuova  
 malata nella corrette che la vedono altre  
 nel bosco sul la strada, moure con  
 se auch un tel petto di gogolo, intonda  
 un lupu che apite le intondazioni della  
 figura con pochi relato venire e para dello

FIG. 2. Sample of patient's handwriting.

fanale → falane) [or combinations of two of the above varieties (e.g., peloso → perolo)] of letters with an isolated neologism.

#### b. Written Naming

The Boston Naming Test was used. When the test had been given as an oral naming task (see Neuropsychological Exam), F.V. had named all the stimuli correctly. The same test was given a week later as a written naming test. This time the patient made 26 errors out of 85 stimuli (30.6%) plus three spontaneous self corrections. All of the errors involved substitutions, deletions, additions, or transpositions of letters (see Appendix II). Errors tended to occur on longer words. The mean lengths of words written correctly and incorrectly were 7.2 and 9.2 letters, respectively ( $t = 3.519$ ;  $p < .001$ ).

#### c. Writing to Dictation

*I. Letters.* F.V. was asked to write to dictation sequences of one to four letters (20 sequences for each length) spelled by the examiner (e.g. /ti/, /em/). All two-or-more letter sequences obeyed orthographic rules of Italian (e.g., /ti/, /ol/, /el/, /ol/, and *not* /el/, /ti/, /ol/, /ol/). He wrote correctly all single letters. Percentages of correct responses on two, three, and four-letter strings were 95, 85, and 85%, respectively. The patient never made more than one error on any sequence. All of the errors were letter substitutions. There was no serial position effect on the longer lists (three and four letters).

*II. Sentences.* F.V. was given 33 high-probability sentences, ranging in length from 3 to 7 words, as a writing-to-dictation test. He wrote only 10 sentences completely correctly (30.3%). Overall, 32 words out of 160 were written incorrectly (20%) (see Appendix III).

*III. Words and nonwords.* A list of 416 stimuli was administered as a writing-to-diction test. Two hundred eighty-three stimuli were words and the remaining 133 were nonwords. Words were controlled for grammatical class, length, frequency, and abstractness.

Errors were slightly less frequent on words (63 errors—22.3%) than on nonwords (41 errors—30.8%). Of the errors on words, 10 resulted in words, while of the errors on nonwords, only 3 resulted in words. Overall, orthographic rules were violated eight times. Errors in writing words were not influenced by any of the variables listed above, except for stimulus length, which exerted a clear influence. Mean length of correctly written stimuli was significantly shorter than mean length of words and nonwords written incorrectly [words:  $t = 2.47$ ;  $p < .02$  (two-tailed); nonwords:  $t = 3.68$ ;  $p < .001$  (two tailed); see Table 1]. On this test, too, F.V. made only spelling errors of the types described previously, with the addition of an isolated gap error (see Appendix IV).

#### *d. Copying Words and Nonwords*

*I. Direct Copy.* F.V. was invited to “copy” (in script) 24 words and 24 nonwords typed in upper case. The patient was allowed to look at the stimulus as many times as he wished. He rarely did so, however, he usually glanced at the stimulus, then copied it quickly. All items were copied correctly.

*II. Copy from memory.* The patient was presented with typewritten stimuli (words:  $N = 94$ ; nonwords:  $N = 53$ ), one at a time. He was invited to inspect them for as long as he needed, until he felt ready to copy them. Then, the patient himself removed the stimulus. Three seconds after the stimulus had been removed the examiner instructed the patient to write the just-presented item. Under this condition, F.V. correctly

TABLE 1  
MEAN LENGTH OF THE STIMULI THAT F. V. WROTE CORRECTLY AND INCORRECTLY ON  
WRITTEN NAMING AND NAMING TO DICTATION

	Written naming	Dictation	
		Words	Nonwords
Correct	7.2	5.8	5.8
Incorrect	9.2*	6.3**	6.6***

\*  $t = 3.519$ ;  $p < .001$ .

\*\*  $t = 2.479$ ;  $p < .02$ .

\*\*\*  $t = 3.687$ ;  $p < .001$ .



copied 93 words (99.1%) and all nonwords [error: coro (choir) copied as caro (dear)].

Another copy-from-memory test was given a few days later. This time, 10 sec elapsed before the patient was allowed to copy. F.V. correctly copied 23/24 (96%) words and 23/24 nonwords (96%) [errors: cinico (cynical) was copied as nicico and bogiata as pogiata].

*e. Writing to Dictation Stimuli That the Patient Had Been Unable to Write in a Previous Task*

In order to control if the stimuli that F.V. had been unable to write presented any special difficulty for him, the patient was asked to write to dictation words ( $N = 36$ ) and nonwords ( $N = 21$ ) that he had written incorrectly on previous occasions, as well as an equal number of words and nonwords of identical length that he had been able to write. There was a very weak tendency to rewrite incorrectly those stimuli that had been written incorrectly before (Table 2). However, performance on stimuli previously written correctly was not error free and, more importantly, he wrote correctly 78% of the words he had written incorrectly previously, thus showing that factors other than intrinsic characteristics of the stimuli are playing a major role in determining writing errors.

*f. Lexical Decision on Writing Errors*

During writing to dictation, F.V. seemed to be aware of many (if not most) of his errors. To further rule out the hypothesis that F.V.'s errors were due to a degraded internal representation of the words he could not write, a lexical decision task was constructed.

The following stimuli were used: 63 words that F.V. had been unable to write; the corresponding nonword errors he had made; 63 words of comparable length that he had written correctly in previous tests; and 63 plausible nonword errors on these words, constructed by the examiner and matched to those made by F.V. Thus, for example, the stimulus *finestra* and F.V.'s error *firestra* were included, as well as the word *canestro* that he had written correctly, and the fictitious substitution error *carestro*, made up by the examiner. On this test, F.V. made only

TABLE 2  
PERFORMANCE OBTAINED REWRITING TO DICTATION SETS OF STIMULI PREVIOUSLY WRITTEN CORRECTLY AND INCORRECTLY

	Previously correct		Previously Incorrect	
	Words	Nonwords	Words	Nonwords
Correct	32	13	28	10
Incorrect	4	8	8	11

two errors, one on a word he had written incorrectly and now failed to recognize as a word, and the other on one of his incorrectly spelled words which he did not reject as a nonword.

*g. Ability to Correct on Sight Errors Made on Writing to Dictation*

In order to assess carefully F.V.'s knowledge of those words which he had been unable to write, the lexical decision test was insufficient, as it merely showed that F.V. was able to distinguish words from nonwords. To get more direct information on the patient's awareness of the orthographic structure of the words that he had written incorrectly, nonword responses that he had produced on previous tests of writing to dictation and of written naming were typed and presented one at a time. F.V. was told that the letter string on the card was a misspelled word that he had produced on a previous test and was invited to guess what the original stimulus was and to write it correctly.

Seventy-five nonwords that had been produced as responses when trying to write real words to dictation were given. F.V. was able to guess the correct stimulus and to write it correctly 47 times (63%). This figure is obviously an underestimation of his ability to correct his errors, as in some instances F.V.'s correction consisted of a word response that was closer to his error than his error was to the original stimulus [e.g., he wrote *castoro* (beaver) as *cartono* and the corrected it as *cartone* (cardboard)]. He made 14 such "errors" (19%). Thus, he was able to correct 82% of his errors. On five occasions attempts at correction gave rise to other writing errors (7%), and on three occasions F.V., while recognizing that his original production was incorrect, produced the same error when trying to correct it. For six stimuli (8%), F.V. could not find a reasonable original target word (see Appendix V).

*h. Ability to Correct Writing Errors upon Auditory Presentation of the Stimulus*

The 28 words that F.V. had been unable to correct on sight and the 56 errors that he made on nonwords were shown to the patient, one at a time in another testing session. While showing each card portraying the error, the examiner pronounced the stimulus in its correct form. F.V. was asked to correct the error on the card.

F.V. managed to correct 24 of the 28 word errors (86%). The following word errors were not corrected appropriately: *racchetta* (racket), written as *ranchecca* and "corrected" as *rachetta*; *pallottoriere* (abacus), written as *pappottoriere* and "corrected" as *pallottoliere*; *altrove* (elsewhere), written as *atrole* and "corrected" as *atrove*; and *fradicio* (soaking), written as *fradiscio* and not corrected. F.V. was able to correct 47/56 errors on nonwords (84%). As with word stimuli, all unsuccessful attempts at correction were very near misses.

### *i. Typing Words and Nonwords*

To explore the possibility that F.V.'s mild tactile sensory deficits may have contributed to errors in formation of letters in writing we had the patient type a set of words and nonwords. The same stimuli as in d. were used. Performance in this typing-to-dictation task was poorer than the writing-to-dictation task [errors on words: 21/72 (29%); errors on nonwords 19/42 (45%)]. However, the types of errors were qualitatively the same in the two tasks.

### *j. Nature of Errors*

As can be seen from Appendixes I–V, errors made on all writing tests were qualitatively identical, independent of the nature of the task (writing to dictation, written naming, and spontaneous/written narrative) and of the nature of the stimulus (i.e., independent of frequency, grammatical class, and concreteness/abstractness for real words, and independent of the stimulus being a word or nonword). Except for an isolated neologism produced in spontaneous writing, all of the errors bore a close resemblance to the stimulus, being classifiable as substitutions, additions, deletions, transpositions, or combinations of two of the "elementary" errors. A gap error was also produced on writing to dictation. The distributions of errors for all words and nonwords are presented in Table 3. It is quite clear that the distributions are remarkably similar.

Most of the errors were nonwords and the very few incorrect word responses occurred both on writing words and nonwords. Also, violations of orthographic rules, though not very frequent (eight in writing to dictation), occurred both with words and nonwords.

No position effect was found; errors occurred with the same frequency in the initial, central, and final positions of the stimuli.

Most of the errors produced by F.V. preserved the orthographic structure of the stimulus. Considering the errors in written naming and writing to dictation, simple substitutions and transpositions account for almost 50%

TABLE 3  
INCIDENCE OF THE VARIOUS ERROR TYPES IN  
WRITING TO DICTATION

	Stimulus	
	Words	Nonwords
Substitutions	63 (46%)	19 (46%)
Insertions	22 (16%)	4 (10%)
Deletions	10 (7%)	4 (10%)
Transpositions	4 (3%)	—
Gap	2 (1%)	—
Mixed	37 (27%)	14 (34%)

of F.V.'s errors. Of the 86 letters (16 vowels, 70 consonants) substituted, 97% respected the orthographic structure of Italian; that is, vowels were substituted for vowels and consonants were substituted for consonants.

## DISCUSSION

The case we have reported is especially interesting because of the purity of the dysgraphic disorder. Aside from the very mild right-hand tactile agnosia the patient was completely normal in language and other cognitive processing. The high selectivity of the disorder makes it possible to draw strong inferences about specific writing processes uncontaminated by deficits to other processing mechanisms.

The major features of F.V.'s dysgraphia can be summarized straightforwardly. The patient made spelling errors in writing both words and nonwords. Reliably more errors were made in writing nonwords than words but the magnitude of the difference was not overwhelming. Another factor that affected F.V.'s writing performance was the length of words and nonwords: More errors were made on the longer items. Interestingly, the dysgraphic deficit was independent of the lexical factors considered (part of speech, frequency, and concreteness) and type of task (written naming and writing to dictation), except for direct copying which was normal and copying from memory which was essentially intact even with a 10-sec delay. The type of errors made were strictly spelling errors resulting mostly in nonwords. The distributions of error types for words and nonwords were very similar.

The interpretation of this pattern of writing deficit is difficult especially when considered in the context of other cases of dysgraphia that have been reported already. That is, difficulties are encountered in proposing a model of writing which, when appropriately "lesioned," can serve as the basis for the explanation of both F.V.'s writing impairment and the patterns of writing impairments already described in the literature.

There are four patterns of impairments that are relevant to this discussion. One pattern is that reported by Beauvois and Dérouesné of a patient who could write nonwords and regularly spelled words well but failed to write irregularly spelled words correctly. Another pattern is that reported by Shallice, who describes a patient who could write words, both regular and irregular, quite well but performed poorly in writing nonwords. The other two patterns concern two cases of deep dysgraphia. Both patients made semantic paragraphic errors, both showed a word-class effect (e.g., writing function words more poorly than nouns and low-frequency words more poorly than high-frequency words), and both performed much worse in writing nonwords than words. However, whereas one of the two patients (J.C., Bub & Kertesz, 1982) made no spelling errors in writing words, the other patient (V.S., Nolan & Caramazza, 1983) made many spelling errors in writing words.

We have already pointed out that the double dissociation between the inability to write nonwords and irregularly spelled words for cases P.R. (Shallice, 1981b) and R.G. (Beauvois & Dérouesné, 1981), respectively, can be taken as evidence for the existence of two independent writing routes: a "lexical" route and a "phonological" (Phoneme-Grapheme Conversion) route. The contrast in performance between these two cases suggests that the two writing routes are completely independent in the sense that the normal functioning of the Phoneme-Grapheme Conversion system is unnecessary for the normal writing of words (case P.R.). Further support for this conclusion comes from case J.C. (Bub & Kertesz, 1982) where the deep dysgraphia can be considered to result from a multi-component deficit: a disruption of the lexicon that differentially affects certain classes of words and a disruption of the Phoneme-Grapheme Conversion system that prevents the writing of nonwords. Despite a disruption of the lexicon (and *not* of the lexical route) this patient was able to spell words correctly. Taking these three cases together we can make a relatively strong argument for the complete independence of the "lexical" and the "phonological" routes in writing.

But, what of the spelling errors reported for V.S. (Nolan & Caramazza, 1983), our case F.V., and other cases of dysgraphia reported in the literature (e.g., case A.F. reported by Hier & Mohr, 1977 and case J.S. reported by Caramazza et al., 1983)? What can be the source of these errors?

Two classes of explanations can be entertained. One class of explanations locates the source of difficulty outside the functioning of the two "routes." That is, the difficulty could be located either prior to the transferring of the graphemic representation into the Grapheme Buffer, in the Output Lexicon itself, or after the transfer operation in the Grapheme Buffer, or in later processing stages. The other class of explanations locates the difficulty directly in the functioning of the two transfer routes, either one or both. We consider both classes of explanations.

#### The Partial Lexical Knowledge Hypothesis

Ellis (1982) has noted that the pattern of misspellings produced by patient A.F. (Hier & Mohr, 1977) can be characterized as reflecting partial lexical knowledge. That is, the patient appeared to know some of the letters or all of the letters in a word but not their order. This description of patient A.F.'s performance applies very well also to our case F.V., patient V.S. (Nolan & Caramazza, 1983), and patient J.S. (Caramazza et al., 1983). Ellis could have intended this observation to be merely a description of the facts or as a hypothesis about the source of spelling errors. We consider his observation as a hypothesis about the mechanism responsible for the dysgraphic performance of patients like our case F.V.

The Partial Lexical Knowledge hypothesis is essentially a claim about

the status of the output graphemic lexicon in patients like A.F. and F.V.—that is, brain damage has destroyed or made inaccessible part of the information about some lexical items. This hypothesis, as an explanation of our patient's performance, is unparsimonious in that it does not address the source of spelling errors in nonwords. Furthermore, it fails to account for some of the word-writing data we have reported.

The strong, and only reasonable, version of this hypothesis maintains that the graphemic structure of some words is partially unavailable to our patient. We assume that the words spelled incorrectly are the words for which only partial information is available and those spelled correctly are those for which there is complete graphemic information (or, were spelled correctly through the Phoneme-Grapheme Conversion route). Thus, if we were to have F.V. rewrite words which he had spelled correctly and incorrectly on a previous occasion we should find that the previously incorrectly spelled words were again spelled incorrectly while the previously correctly spelled words were once again spelled correctly. However, as we have reported (task e), on retesting F.V. performed about equally well on words he had previously spelled incorrectly and correctly. It is not likely, then, that the deficit responsible for the dysgraphia in our patient (and perhaps cases A.F., V.S., and J.S. as well) is a disruption of the information represented in the Output Graphemic Lexicon.

#### The Grapheme Buffer Deficit Hypothesis

The assumption has been made that a Grapheme Buffer plays a crucial role in the writing process (Ellis, 1982; Nolan & Caramazza, 1983). The Grapheme Buffer is assumed to hold an abstract graphemic representation of the to-be-written item in preparation for more peripheral output mechanisms which actually carry out the writing process. Thus, the Grapheme Buffer will receive inputs both from the lexicon (in the case of words) and from the Phoneme-Grapheme Conversion system (in the case of nonwords). It has also been assumed by Nolan and Caramazza, without direct empirical support, that the representation held in the Grapheme Buffer decays very rapidly and must be refreshed in order to serve its function of guiding lower level output processes. A disruption of the Grapheme Buffer should result in pure dysgraphia. Specifically, the prediction is made that in such a case we should observe an equal pattern and quantity of spelling errors for words and nonwords with more errors on longer items. Furthermore, this hypothesis predicts that there should be no effects of grammatical class nor effects of frequency or concreteness in word writing.

The pattern of writing performance found in F.V. generally conforms to these predictions. The discrepancy in writing performance between words and nonwords could be attributed to the greater success of a guessing or monitoring strategy with words when the patient had only

partially useful information in the Grapheme Buffer. Thus, the Grapheme Buffer Deficit hypothesis accounts quite well for the pattern of impairments in written naming and writing to dictation found in our patient.

The hypothesis, however, fails to explain F.V.'s excellent performance in the copying-from-memory task. In this task F.V. performed essentially flawlessly even when a 10-sec delay was introduced between the presentation of the stimulus and the response. Models of writing have assumed that the Grapheme Buffer is required for normal copying-from-memory (e.g., Ellis, 1982). Consequently, the Grapheme Buffer Deficit hypothesis predicts that performance should be impaired in this latter task, contrary to the results obtained. Of course, we could assume that in copying tasks subjects have available the alternative strategy of bypassing the Grapheme Buffer by treating the stimulus not as a *graphemic* pattern but as a *graphic* pattern. The point here is that in the case where the Grapheme Buffer is impaired a patient could rely on a nonlinguistic visual memory system to carry out the task. This latter explanation does not apply in this situation since the patient "copied" the *printed* stimulus words in *script*, thus implicating a graphemic and not a graphic process. Thus, we are forced to conclude that the Grapheme Buffer Deficit hypothesis fails to provide a full explanation of F.V.'s spelling impairment.

The two hypotheses we have just considered located the source of writing difficulty either in the Lexicon or in the Grapheme Buffer. Alternatively we could locate the difficulty in the process involved in transferring information from the Lexicon to the Grapheme Buffer. Next we consider hypotheses that locate the difficulty at this latter level of processing.

### A Dual Deficit Hypothesis

One possibility to be considered is that there are independent sources of difficulty for the nonword and word spelling errors. We could assume that both the lexical and the phonological routes are impaired in our patient. While it is not unreasonable to propose a multicomponent deficit hypothesis to explain a well circumscribed symptom complex, such as that we have described for F.V., we do not think that this hypothesis is consistent with the observations reported. Specifically, if the source of difficulty for writing words and nonwords were to be located in different mechanisms, then, we would expect the patterns of errors for these two types of stimuli to be different. However, as we have noted, F.V.'s patterns of errors on words and nonwords were very similar. It is unlikely, therefore, that different mechanisms contributed to the misspellings produced by our patient. This suggests that we should seek an explanation based on a common source of difficulty for the misspellings of words and nonwords.

### The Phoneme–Grapheme Conversion Hypothesis

We have assumed thus far a dual route model of writing. As pointed out in the introduction, however, it is possible that in languages with transparent orthographies (i.e., one-to-one correspondences between sound and spelling), writing always involves the conversion of phonological to graphemic representations. If we were to adopt a single route model for Italian we could account for the pattern of F.V.'s performance by assuming that the patient has an impairment in the Phoneme–Grapheme Conversion system. This hypothesis can account for the similarity of spelling errors for words and nonwords but fails to account for the small but reliable difference in error rates for words and nonwords. The better performance with words suggests that the patient had word-specific (graphemic) information which he could use in writing. In other words, it would appear that graphemic information independent of the Phoneme–Grapheme Conversion system may be available to our patient. This suggests that, even in languages with a transparent orthography, writing may involve a dual route process.

A possible solution to the apparent conflict between wanting an explanation based on a deficit to a single mechanism and dual route writing system is to reject the assumption of complete independence between the lexical and the phonological routes.

Nolan and Caramazza (1983) have proposed, on the basis of their analysis of a case of deep dysgraphia, that writing words (in written naming, spontaneous writing, and writing to dictation) involves the selection of a graphemic entry in the lexicon which is placed in a Grapheme Buffer while subsequent, lower level writing processes are executed. Concurrently with the selection of a graphemic form in the lexicon a corresponding phonological form is selected and placed in a Phonological Buffer. The phonological form in the Phonological Buffer can be translated into the graphemic form through a Phoneme–Grapheme Conversion process and serve as input into the Grapheme Buffer to “refresh” the rapidly decaying graphemic representation in this buffer. However, the role of the conversion process in refreshing graphemic representations in the graphemic buffer may be of limited utility in a language like English, rich as it is in irregularly spelled words and ambiguous phoneme/grapheme mappings (e.g., /get/ → *gait* or *gate*). Furthermore, in its present form the model allows refreshing of the representation in the Grapheme Buffer only through the Phoneme–Grapheme conversion of the representation temporarily held in the Phonological Buffer further exacerbating this limitation. Nonetheless, this model predicts that a lesion in the Phoneme–Grapheme Conversion system should result in spelling errors in writing words and nonwords. The reason for predicting spelling errors for words is based on the assumption that the rapidly decaying representation in the Grapheme Buffer can be refreshed only through the Phoneme–Grapheme Conversion



system, a more realistic possibility in a language with transparent orthography like Italian. In this latter case if the conversion system is disrupted, representations held in the Grapheme Buffer cannot be refreshed and should result in spelling errors.

The pattern of writing impairments we have reported for F.V. is in close agreement with that predicted by the Phoneme-Grapheme Conversion Deficit hypothesis. However, this hypothesis rests on the assumption that the functioning of the lexical route is not entirely independent of the Phoneme-Grapheme Conversion system and, therefore, is seemingly in conflict with the data reported by Shallice for case P.R. If case P.R. has a deficit in the Phoneme-Grapheme Conversion system, as indicated by his performance in writing nonwords (18% correct), then on the basis of Nolan and Caramazza's assumption of the contribution of the Phoneme-Grapheme Conversion system to the lexical route in writing P.R. should have produced a higher proportion of spelling errors than the 6% reported by Shallice. It may be possible, however, to reconcile the discrepancy in the difference in performance in spelling errors on words and nonwords of our case F.V. (and Nolan and Caramazza's V.S.) and Shallice's P.R. if we assume that the representation held in the Grapheme Buffer can be refreshed not only through the Phoneme-Grapheme Conversion system but also directly through the lexicon and that subjects differ in the extent to which they use the alternative refreshing systems.

In the model of writing proposed by Nolan and Caramazza the only mechanism for refreshing representations held in the Grapheme Buffer was through the input from the Phoneme-Grapheme Conversion system. If we were to assume instead that representations in the Grapheme Buffer could also be refreshed directly from the lexicon either by keeping the lexical entry to be written active in the lexicon and periodically placing this entry in the Grapheme Buffer or, alternatively, by reactivating a lexical entry in the lexicon through a feedback system from the Phonological Buffer and placing the activated lexical entry in the Grapheme Buffer, we could account for the differential rates of spelling errors on words when the Phoneme-Grapheme Conversion system is impaired. When a patient relies heavily on the Phoneme-Grapheme Conversion system to refresh the Grapheme Buffer there will be a high proportion of spelling errors in words; when a patient relies primarily on the lexicon to refresh the Grapheme Buffer there will be relatively few spelling errors in words in contrast to nonwords.

If the arguments we have developed are accepted as reasonable the discrepancy in results obtained for F.V. and P.R. does not undermine the claim that the same mechanism is impaired in the two patients. All we would have to assume is that F.V. relies extensively on the Phoneme-Grapheme Conversion system to refresh representations in the Grapheme Buffer. P.R. instead relies more on the lexical route for refreshing the Grapheme Buffer.

## CONCLUSIONS

We have presented several accounts for the pattern of writing impairment in a case of pure dysgraphia. None is fully satisfactory. The two hypotheses that best account for the full range of data considered are the Grapheme Buffer Deficit and the Phoneme–Grapheme Conversion Deficit. The Grapheme Buffer deficit hypothesis accounts for F.V.'s performance in writing to dictation, written naming, and spontaneous writing very well but fails to account for the near-perfect performance in delayed copying. The Phoneme–Grapheme Conversion Deficit hypothesis receives strong support from the pattern of performance of our case F.V. but leads us to make strong assumptions about differences in the use of Phoneme–Grapheme Conversion system in different languages and, more importantly, to the postulation of alternative ways of refreshing representations held in the Grapheme Buffer. It would have been preferable not to have had to make this latter assumption as it makes the model of writing we are considering very powerful (i.e., difficult to assess empirically). However, the model is not immune to falsification—the existence of an Italian (e.g., or a speaker of Serbo-Croatian) patient who makes spelling errors only on nonwords and is otherwise like F.V. in other respects of performance would make our assumptions about the role of the Phoneme–Grapheme Conversion system in writing through the lexical route highly implausible.

Clearly, considerably more research is needed to resolve the issues we have raised concerning the possible roles of the Grapheme Buffer and of the Phoneme–Grapheme Conversion system in writing. However, despite the remaining problems the usefulness of the general architecture of the writing system we have considered as a guide to the investigation of writing disorders is amply demonstrated as is the usefulness of data from cognitively impaired patients to constrain and refine models of cognitive processing.

## APPENDIX I

Written Narrative: Little Red Riding Hood<sup>1</sup>


---

	soprannome perché
E' una bambina che ha avuto questo	soprammone merché la
Is a young girl who has this nickname	because her

mamma	confezionato	bimba
magma le ha convesionato un mantello rosso,	che la bamba	
mother had tailored for her a red cape	that the girl	

indossa	dalla
intondda anche oggi che é in visita dalle nonna malata	
is wearing also today that she is visiting her grandmother	

<sup>1</sup> The middle line represents what the patient wrote. The bottom line is a literal translation. The correct spelling of F.V.'s errors are presented in the top line.

APPENDIX I—*Continued*

nella casetta che la vecchina abita nel bosco.  
 who is sick, in the house that the old woman lives in the woods.

Sulla porta sé fragole (foglie)  
 Nulla strada, monta con se anche un bel cesto di goglie  
 On the way, she brings also a nice basket full of berries:

incontra lupo capite bimba  
 intonta un lupo che apite le intenzioni della bigna con  
 she meets a wolf that, understanding the idea of the girl, with a

salti casa  
 pochi salti arriva a casa della nonna la divorza si veste  
 few jumps arrives to grandmother's house, eats her, dresses

della cuffia e della camicia poverina  
 comiglia della porevina,  
 himself with the kerchief and the nightgown of the poor woman

infilta bimba  
 si ciusfila nel suo letto ed attende l'arrivo della minda.  
 crawls into her bed and waits for the young girl.

meraviglie bambina  
 Come entra, alle meriamiglie della mandima per le  
 As soon as she gets in, while the young girl wonders for the

?? orecchie (???) muso aguzzo rapidamente ingoia  
 oltre occhiericchi ed il mulo agruzzo rapidamende la ingola.  
 ?? ears (???) and the sharp face quickly swallows her.

cacciatore urla  
 Un cecciotore alle ulta della bambina rapidamente squarta  
 A hunter hearing the screams of the girl quickly slaughters

Cappuccetto  
 il lupo e libera accuccetto rosso e la nonna.  
 the wolf and sets free Little Red Riding Hood and her grandmother.

## APPENDIX II

### Written Naming<sup>2</sup>

#### I. Substitutions

portafoglio	(wallet)	portofoglio
scala mobile	(escalator)	scala momile
girandola	(pinwheel)	girardola

<sup>2</sup> A plus sign (+) indicates a correct response or self correction.

APPENDIX II—*Continued*

goniometro	(protractor)	gogiometro
tavolozza	(easel)	tovolozza
fungo	(mushroom)	lungo +
pagaia	(paddle)	palaia
ghianda	(acorn)	chianda
etichetta	(label)	etichecca
cammello	(camel)	connello
lucchetto	(latch)	lucchecco
II. Insertions		
rinoceronte	(rhinoceros)	rinnoceronte
elica	(propeller)	elica
III. Deletions		
slittino	(sled)	littino
clessidra	(hourglass)	clessida
nodoscorsoio	(noose)	nodoscorso
unicorno	(unicorn)	unicono
IV. Mixed errors		
fischietto	(whistle)	spichietto
castoro	(beaver)	cartono
racchetta	(racquet)	ranchecca
sonaglino	(rattle)	solanglino
stetoscopio	(stethoscope)	stecospio
museruola	(muzzle)	murerola
sfinge	(sphinx)	sfengie
pallottoliere	(abacus)	pappottoriere

## APPENDIX III

Writing Sentences to Dictation<sup>3</sup>

S Giovanni ha due macchine (John has two cars).

R Giovaani

S Aldo gli tocca il braccio (Aldo touches his arm).

R si locca barscio

S Il nemico è in mezzo a noi (enemies are among us).

R moi

<sup>3</sup> The sentences dictated are indicated by "S." A translation is given in parentheses. The words spelled incorrectly are presented immediately below the dictated word.

APPENDIX III—*Continued*

---

S Il gatto è salito sul tavolo (The cat has jumped on the table).

R saluto tamvolo

S Non sei alto (you are not tall).

R aldo

S Antonio è un bravo medico (Antonio is a good doctor).

R bavo

S Gianni è seduto sulla sedia (Gianni is sitting on a chair).

R stedia

S La gatta ha avuto quattro gattini (the cat had four kittens).

R gentili

S Dimmi che non è vero (tell me that it is not true).

R veno

S Questa volta me la paghi (this time you will pay for it).

R Ouesta pachi

S Enzo ha comprato una nuova macchina (Enzo bought a new car).

R matticha

S Una casa di mattoni rossi (a red brick house).

R cara mattori

S Guarda che cosa hai fatto (look what you have done).

R Quara

S Il gatto è salito sopra il tavolo (the cat jumped on the table).

R tovolo

S Ugo non glielo ha detto (Ugo did not tell it to them).

R ce lo dlto

S Antonio è un medico bravo (Antonio is a doctor good).

R l nmedico

S Luigi ha l'influenza (Luigi has got the flu).

R l'influcenza

S Questo non si tocca (this must not be touched).

R Cresto

S Carlo è veloce (Carlo is fast).

R veroce

APPENDIX III—*Continued*


---

S Il cane è dentro la cuccia (the dog is in the kennel).

R detto

S Il nemico è tra noi (the enemy is among us).

R nemimo

S Il nuovo modello mi piace (I like the new model).

R mi \_\_ca

S L'aquila è un uccello (the eagle is a bird).

R L'aquilo

S Mi rado la mattina (I shave in the morning).

R mattino

---

## APPENDIX IV

## Writing to Dictation

## I. Substitutions

## a. Words

finestra	(window)	firestra
beffa	(joke)	feffa
gente	(people)	genne
lode	(congratulations)	lede +
ovvero	(that is)	ovveno
brusco	(sudden)	frusco
lungo	(long)	bungo
avanti	(ahead)	aventi +
sembravi	(you looked)	sempravi
tenevi	(you held)	denevi
nasceva	(he was born)	nasciva
palazzo	(building)	palozzo
tatto	(tact)	tappo +
giovane	(young)	giovale
soltanto	(only)	seltanto
invano	(in vain)	invao
vissi	(I lived)	fissi +
armadio	(cupboard)	armagio
finivo	(I ended)	vilivo
sembrava	(he seemed)	semprama
fontana	(fountain)	fortona
macchina	(car)	micchima
libero	(free)	limeno
mondo	(world)	nordo

## b. Nonwords

faspedio	faspenio
addarso	addarno
sopreva	sopresa

## APPENDIX IV—Continued

---

cudo	curo +
precio	prechio
nistia	nistra
nacchi	necchi
maggiodo	naggiodo
sembrapo	semprapo
imbelfo	impelfo
ombergo	onbergo
asciarto	acciarato
crama	grama
tatografo	fatografo
ugaco	ucaco
splivo	sflivo
basbi	basti +
fiubivo	fiumivo
pambravi	pampravi

## II. Insertions

## a. Words

piede	(foot)	pietre
tizio	(guy)	tizzio
agio	(ease)	angio
gassoso	(gaseous)	grassoso
tavolo	(table)	travolo
modo	(way)	moldo
discorso	(discourse)	dirscorso
gruppo	(group)	grouppo
silenzio	(silence)	silenzio
fradicio	(soaking)	fradiscio
ciao	(hello)	scialo +
tranne	(except)	tracne
buone	(good)	buoene
servi	(servants)	scervi
odora	(he smells)	oldora
veleno	(poison)	velendo

## b. Nonwords

infatra	infantra
turmilo	sturmilo
cianto	scianto
colvo	colovo

## III. Delections

## a. Words

dieta	(diet)	deta
scrupolo	(scruple)	scrupo
decennio	(decade)	decenni +
durante	(during)	durant

## APPENDIX IV—Continued

---

	b. Nonwords	
delba		deba
stovidi		sovidi
lantrani		lantani
sconfale		sonfale
	IV. Transpositions	
	a. Words	
fanale	(street lamp)	falane
materno	(maternal)	marteno
appresso	(after)	appersso
	V. Mixed errors	
	a. Words	
fiutavo	(I smelled)	fiuato
ardito	(daring)	arido +
escludo	(I exclude)	esrudo
peloso	(hairy)	perolo
altrove	(elsewhere)	artrole
sicuro	(sure)	siluco
circa	(approximately)	cifra +
scaffale	(shelf)	scalfare
pudore	(modesty)	purdode
ciocca	(flock)	chioccia +
cappa	(cape)	trappa
albo	(album)	alevo
quassù	(up here)	coasso
accanto	(near)	attaccando +
ciliegia	(cherry)	clicenga
miscuglio	(mixture)	miscuco
	b. Nonwords	
tova		trone
racizzi		rascitti
beritto		pertitto
porliamo		polgiamo
esmadio		empadio
girvi		civi
peltemmo		meltemo
insiepo		sememo
persoze		percse
bialeva		bariela
ambulmo		anmulmo
mabio		mambo +
tepogo		setopo
accansi		accasne

---



## APPENDIX V

### Errors That the Patient Did Not Correct on Sight

Stimulus	Error on writing to dictation	Correction on sight	Response to auditory presentation
1. Errors in which the patient produces another real word as response			
gente	genne	gemme	+
fontana	fortona	fortuna	+
cammello	connello	coltello	+
libero	limeno	limone	+
castoro	cartono	cartone	+
servi	scervi	scrivi	+
slittino	littino	lettino	+
dieta	deta	dito	+
peloso	perolo	pirolo	+
scaffale	scalfare	scalfire	+
fiutavo	fiuato	fiutato	+
albo	alevo	allevo	+
fischietto	spichietto	specchietto	+
sfinge	sfengie	spinge	+
2. Errors in which the patient produces a different error as response			
escludo	esrudo	esegulo	+
etichetta	eticella	etichecca	+
ciliegia	clicenga	ciliega	+
pudore	purdode	prudore	+
racchetta	ranchecca	ranchetta	rachetta
3. Errors in which the patient produces the same error as response			
coperchio	coperpio	coperpio	+
fradicio	fradiscio	fradiscio	fradiscio
pallottoliere	pappottoriere	pappottoriere	pallottoriere
4. Errors for which the patient was unable to find a reasonable stimulus			
gassoso	grassoso	n.r.	+
perfino	perpinso	n.r.	+
sicuro	siluco	n.r.	+
beffa	feffa	n.r.	+
sonaglino	solanglino	n.r.	+
altrove	artrole	n.r.	atrove
5. Errors on nonwords that the patient was unable to correct following auditory presentation of the stimulus			
pambravi	panvari		panbravi
porliamo	polgiamo		polgiamo
ombergo	onrbergo		onbergo
ambulmo	anmulmo		anbulmo
imbelfo	inbelfo		inpelfo
girvi	civi		givi
peltemmo	meltemmo		meltemmo
racizzi	rascitti		rsciti
precrio	prequio		n.r.

## REFERENCES

- Beauvois, M. F., & Dérouesné, J. 1981. Lexical or orthographic agraphia. *Brain*, **104**, 21-49.
- Bub, D., & Kertesz, A. 1982. Deep agraphia. *Brain and Language*, **17**, 147-166.
- Caramazza, A., & Berndt, R. S. (in press). A multi-component deficit view of agrammatic Broca's aphasia. In M. L. Kean (Ed.), *Agrammatism*. New York: Academic Press.
- Caramazza, A., Berndt, R. S., & Basili, A. 1983. The selective impairment of phonological processing: A case study. *Brain and Language*, **18**, 128-174.
- Coltheart, M. 1981. Disorders of reading and their implications for models of normal reading. *Visible Language*, **15**, 245-286.
- Coltheart, M., Patterson, K. E., & Marshall, J. C. (Eds.) 1980. *Deep dyslexia*. London: Routledge & Kegan Paul.
- De Renzi, E., & Faglioni, P. 1978. Normative data and screening power of a shortened version of the Token Test. *Cortex*, **14**, 41-49.
- Ellis, A. W. 1982. Spelling and writing (and reading and speaking). In A. W. Ellis (Ed.), *Normality and pathology in cognitive functions*. New York/London: Academic Press.
- Hier, D. B., & Mohr, J. P. 1977. Incongruous oral and written naming: Evidence for a subdivision of Wernicke's aphasia. *Brain and Language*, **4**, 115-126.
- Kaplan, E., & Goodglass, H. 1976. *Boston Naming Test*. Boston: Boston University School of Medicine.
- Marcel, T. 1980. Surface dyslexia and beginning reading: A revised hypothesis of the pronunciation of print and its impairments. In M. Coltheart, K. E. Patterson, & J. C. Marshall (Eds.), *Deep dyslexia*. London: Routledge & Kegan Paul.
- Marcie, P., & Hecaen, H. 1979. Agraphia: Writing disorders associated with unilateral cortical lesions. In K. M. Heilman & E. Valenstein (Eds.), *Clinical neuropsychology*. Oxford: Oxford Univ. Press.
- Morton, J. 1980. The logogen model and orthographic structure. In U. Frith (Ed.), *Cognitive processes in spelling*. New York/London: Academic Press.
- Nolan, K. A., & Caramazza, A. 1983. An analysis of writing in a case of deep dyslexia. *Brain and Language*, **20**, 305-328.
- Shallice, T. 1981a. Neurological impairment of cognitive processes. *British Medical Bulletin*, **37**, 187-192.
- Shallice, T. 1981b. Phonological agraphia and the lexical route in writing. *Brain*, **104**, 413-429.