

An Analysis of Writing in a Case of Deep Dyslexia

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In tests of her ability to produce written and spoken language, this deep dyslexic patient produced semantic, visual, and derivational errors, including functor substitutions, and exhibited part-of-speech and abstractness effects in oral reading, oral and written naming, and writing to dictation, but not in repetition of single words and copying from memory. This patient therefore provides confirmation of the hypothesis presented in Nolan and Caramazza (1982) that the defining symptoms of deep dyslexia will be observed in responses to any task which requires lexical mediation. The patient's written responses in all tasks but direct copying were characterized by spelling errors which included transpositions, omissions, substitutions, and additions of letters. A model of writing is proposed which explains these errors in terms of a disruption of a phoneme-grapheme conversion process which normally functions to prevent decay of information from a Graphemic Buffer.

Deep dyslexia, a fairly well-known form of acquired dyslexia, is characterized by a striking pattern of impairments in oral reading. The deep dyslexic reader (a) is unable to derive phonology from print nonlexically, (b) produces visual, derivational, and semantic errors in reading single words aloud, (c) has greater difficulty in reading aloud less concrete or imageable words, and (d) exhibits a part-of-speech effect in oral reading such that nouns are read better than adjectives and verbs, and functors are read worst of all. Coltheart (1980a) has argued that the production of semantic errors in oral reading guarantees the occurrence of the other symptoms of deep dyslexia and, in fact, this claim has not been contradicted by any reported case. Thus, any patient who produces semantic errors in reading aloud can be classified as a deep dyslexic reader.

Most theoretical and investigative treatments of deep dyslexia have regarded this syndrome as a reading disorder. However, in a recent paper (Nolan & Caramazza, 1982) we have reported a deep dyslexic patient,

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B.L., in whom the defining symptoms of deep dyslexic reading are duplicated in repetition, writing, and naming. The dual-deficit model proposed to account for the modality-independent impairments observed in B.L. includes a "central" disruption of the lexical system which results in an elevation of thresholds throughout the lexicon, exaggerating the normally present concrete/abstract threshold gradient. An additional disruption of phonological processing prevents the use of grapheme-phoneme conversion rules in reading aloud. Thus, deep dyslexic reading results from the lexical disruption in conjunction with the loss of the "back-up" reading system ordinarily provided by grapheme-phoneme conversion. However, the lexical disruption which we propose to account for deep dyslexic reading should be observable in any task which requires lexical mediation. Thus, a deep dyslexic reader should also be a deep dyslexic "namer" and a deep dyslexic writer (at least for spontaneous writing), since both of these tasks require that reference be made to the disrupted lexicon. Since it is not clear that even regularly spelled English words can be written correctly without lexical mediation (how, for example, is a phoneme-grapheme conversion system able to prevent "cake" from being written as "kake" or "kaik" ?), we also assume that deep dyslexic readers should exhibit deep dyslexic error patterns in writing to dictation.

However, the extent to which phonological processing is disrupted in deep dyslexia remained open to empirical investigation. For the lexical disruption to have an observable effect on oral reading of regularly spelled words and nonwords, grapheme-phoneme conversion must be impaired. The disruption of phonological processing suffered by B.L. obviously included more than loss of grapheme-phoneme conversion; B.L. was also unable to use acoustic-phonemic conversion to by-pass the lexicon during repetition of single words and thus exhibited the part-of-speech and abstractness effects and produced semantic errors and functor substitutions in repetition. For B.L., then, either the phonological processing system itself was disrupted, or it was rendered inaccessible from both auditory and visual input. Although it is more parsimonious to assume that the phonological processing system is disrupted than to posit two separate impairments to the access routes to the phonological processing system, these alternatives could not be distinguished on the basis of the data obtained from one patient. We therefore postulated that deep dyslexia could occur if the phonological processing system were not disrupted, but only inaccessible from visual input and if the lexical system were concurrently disrupted. A patient who suffered this combination of disruptions should exhibit the typical deep dyslexic pattern of performance in reading, writing spontaneously and to dictation, and naming, since each of these tasks requires lexical mediation. However, repetition of single words would be unaffected by the lexical disruption since auditory-phonemic conversion could be used to by-pass the lexicon.

In this paper we will report a patient who exhibits this postulated pattern of impairments, thus providing confirmation for the hypothesis that deep dyslexia may occur with or without a concurrent impairment in repetition, and that impairments in naming and writing will cooccur with deep dyslexic reading. However, the writing errors produced by this patient are not solely of the predicted deep dyslexic type; that is, in addition to semantic and visual paraphasias and functor substitutions, this patient also produced numerous "spelling errors." Thus, the patient exhibits a disruption of writing beyond that which can be explained in terms of her reading disability. Nevertheless, we feel it is important to attempt to explain the writing impairment within a framework that is consistent with our understanding of the reading process. In this paper, therefore, we describe the patient's reading and writing abilities rather extensively, and discuss the data in terms of current models of deep dyslexic reading and of writing.

CASE HISTORY

V.S., a white female, was 57 years old at the time this study was initiated in 1981. She had completed the 12th grade and had been employed as a legal secretary prior to a left cerebrovascular accident in 1971. V.S. was originally identified as a deep dyslexic by Marin, Saffran, and Schwartz (1975; see also Marin, 1980; Saffran, Bogyo, Schwartz, & Marin, 1980; Saffran & Marin, 1977; Saffran, Schwartz, & Marin, 1976; Schwartz, Saffran, & Marin, 1977). In addition to her reading impairments, V.S. also exhibits the comprehension and production deficits of a Broca's aphasic. She also suffers articulatory difficulties, particularly with multisyllabic words and consonant blends.

CT scan taken in 1975 revealed lucency of the left temporal lobe and left temporo-parietal region, with definite involvement of the left supra-marginal gyrus and probable involvement of the left angular gyrus. There may be some involvement of the posterior portion of the inferior frontal gyrus, based on widening of the Sylvian fissure and dilatation of the left frontal horn of the lateral ventricle. These lucencies are consistent with the clinical history of old infarction.

ORAL READING

V.S. was asked to read aloud single items from a list of 78 words, including high and low frequency, concrete and abstract nouns and verbs, and functors, and 29 nonwords, 16 of which were pseudohomophones. The results of this task are given in Table 1. As expected, V.S.'s performance was best for nouns and better for verbs than for functors. She was unable to read any nonwords correctly although her responses to two of the pseudohomophones differed from the correct pronunciation by only one phoneme ("boks" was pronounced "books" and "dawg"

TABLE 1
 PERCENTAGE CORRECT ORAL READING OF WORDS
 AND NONWORDS

	<i>n</i>	% Correct
Nouns	20	40
Concrete	10	60
High frequency	5	80
Low frequency	5	40
Abstract	10	20
High frequency	5	40
Low frequency	5	0
Verbs	20	20
Concrete	10	40
High frequency	5	40
Low frequency	5	40
Abstract	10	0
High frequency	5	0
Low frequency	5	0
Functors	38	16
High frequency	19	26
Low frequency	19	5
Nonwords	29	0
Pseudohomophones	16	0
Pronounceable	13	0

was pronounced "dawn"). However, these errors appear to reflect a strategy of attempting to read nonwords as visually similar real words. In attempting to read real words V.S. produced 5 semantic errors, 4 visual errors, 2 derivational errors, and 13 functor substitutions. Other errors were predominantly articulatory errors, produced mainly on words of two or more syllables.

V.S.'s oral reading of single words therefore conforms to the pattern of impairments which characterize deep dyslexia. She is unable to derive phonology from print nonlexically, as demonstrated by her inability to read nonwords. She exhibits both a part-of-speech effect and an abstractness effect (see Table 1) and produces semantic, visual, and derivational paralexias. V.S. was also asked to read other lists of words aloud; however, the results of these other reading tests will be reported in the sections of this paper for which they provide appropriate comparisons to her ability to deal with these words in other tasks.

LEXICAL ACCESS

Some recent attempts to account for the symptom-complex of deep dyslexia have accorded considerable weight to the extensive left-hemisphere damage that is typically seen in deep dyslexic patients and have proposed

that deep dyslexics' left-hemisphere lexicons cannot be accessed by visual input. Instead, it is assumed that a mute right-hemisphere lexicon must be accessed and that the information retrieved from the right-hemisphere lexicon must be transferred to the left hemisphere for spoken output. The plausibility of the right-hemisphere hypotheses (Coltheart, 1980b; Saffran et al., 1980) of deep dyslexia is critically dependent upon the assumption that the right-hemisphere lexicon which is presumed to be used for oral reading in deep dyslexia lacks orthographic entries for certain words, abstract words in particular, and therefore produces visual errors in attempting to read these unrepresented words. Since the right-hemisphere hypotheses also hold that the left-hemisphere lexicons of deep dyslexics cannot be accessed by visual input, deep dyslexics' performance on lexical decision tasks with visually presented stimuli must likewise be mediated by their incomplete right-hemisphere lexicons. These patients' lexical decision performance should reflect the relative incompleteness of the right-hemisphere lexicon, so that more "misses" will be seen with visually presented items as opposed to auditorily presented items.

To test this prediction, auditory and visual versions of a single lexical decision task were administered in two separate sessions. The word stimuli in this task consisted of both abstract and concrete nouns, verbs, adjectives, and adverbs, of both high and low frequency, as well as high and low frequency functors. The nonword stimuli were derived from real nouns, verbs, adjectives, adverbs, and functors. V.S.'s lexical decision performance was very good with either method of presentation. Although the "miss" rate was slightly higher in the visual version of the task (12% for visual as opposed to 6% for auditory), the lower miss rate in the auditory version was accompanied by an increase in the number of false alarm errors (3% visual, 13% auditory). The difference in performance on these two versions of the same task is apparently due to a criterion shift ($\beta = 2.97$ visual, $.56$ auditory) rather than differential sensitivity ($d' = 3.1$ visual, 2.7 auditory, no significant difference between d 's). In addition, the prediction that more misses should occur for abstract words in the visual test was not upheld; V.S. missed 12.5% of the abstract words in each test. Therefore it does not seem that V.S. is consulting two different lexicons, but is merely using a less stringent criterion in evaluating auditorily presented items.

In early tests of her oral reading, it became apparent that V.S. simply omitted grammatical suffixes (e.g., -ly, -ing). When this was pointed out to her, she indicated that she did not know what to make of them, but began to acknowledge their presence by pronouncing "it" after the root portion of a suffixed word. In an effort to determine whether V.S. had any knowledge of the meaning or function of grammatical suffixes a lexical decision task was devised in which real word items included both

suffixed and nonsuffixed items, matched as nearly as possible for length and frequency. Nonword items were either real words which had been inappropriately suffixed (e.g., *stopy*) or pronounceable nonsense strings (e.g., *slarem*). If V.S. was unable to attach any meaning or function to grammatical suffixes, she should be unable to distinguish between appropriately and inappropriately suffixed words. The results of this test are given in Table 2. Although she performed better on nonsuffixed items than on suffixed items ($d' = 3.4$ nonsuffixed, 1.9 suffixed), her performance on suffixed items was still much better than would be expected if she had no comprehension of grammatical suffixes (85% correct on suffixed words and 81% correct on suffixed nonwords). That is, to correctly accept 85% of the appropriately suffixed words while incorrectly accepting only 19% of the nonwords formed by inappropriately suffixing real words, V.S. must have access to some representation of the meaning or function of grammatical suffixes which allows her to judge whether they have been appropriately attached to a word. Data from other deep dyslexic patients suggest, however, that the representations for grammatical suffixes which enable them to distinguish appropriately from inappropriately suffixed items in lexical decision tasks are insufficient for discriminating between derivationally related forms in tests of comprehension (Patterson, 1980).

Despite her inability to read these suffixes aloud correctly, then, it is not the case that V.S. does not have access to representations for grammatical suffixes. Although the issue of whether words are stored in morphologically decomposed state remains unresolved, V.S.'s ability to judge whether a word has been suffixed appropriately, together with her inability to pronounce these suffixes, suggests that although she is able to access representations for stems and suffixes alike, she cannot reliably access output representations for suffixes. If suffixed words are stored in the lexicon as whole units, we would not expect to find a patient who could access the input representations of suffixed words but could pronounce only the stem portions of such words. However, if words are stored in morphologically decomposed form, V.S.'s performance is consistent with the view that she has difficulty accessing the appropriate

TABLE 2
LEXICAL DECISION PERFORMANCE FOR SUFFIXED
AND NONSUFFIXED ITEMS

	Suffixed (%)	Non- suffixed (%)	Overall (%)
Words	85	93	89
Nonwords	81	96	88
Overall	83	94	

output forms for certain items. These data merely require that we add grammatical suffixes to the list of items for which output representations cannot be accessed, and therefore provide evidence (albeit weak evidence) in favor of the hypothesis that words are represented in the lexicon in morphologically decomposed form.

TESTS OF PHONOLOGICAL PROCESSING

It was apparent from V.S.'s inability to read nonwords aloud that she lacked the ability to derive a suitable phonological code for a string of letters and/or to use such a nonlexically derived code for pronunciation. In order to assess V.S.'s ability to derive phonological representations for nonword letter strings independently of her ability to use these representations for pronunciation, V.S. was given a task in which she was asked to select which of two nonword strings would be pronounced like the word read to her by the experimenter. A set of 32 real words was selected so that 2 pseudohomophones could be constructed for each word, one visually similar to the word and the other visually dissimilar to it. Two sets of nonhomophonic nonwords were then constructed to match the pseudohomophones in terms of their visual similarity to the words. Thus, for the word "queen," the visually similar pseudohomophone was QUEAN and the visually similar nonhomophone was QUEEM. The visually dissimilar pseudohomophone for "queen" was KWENE and the visually dissimilar nonhomophone was KWEME. All possible pairs of pseudohomophone and nonhomophone for each word were presented in the course of the test. The results of this test are given in Table 3; it appears that when only one item was visually similar to the word V.S. made her decision on the basis of visual similarity. When both alternatives were similar to the word, she was apparently forced to guess. However, when neither alternative bore a strong resemblance to the word, V.S. seems to have been able to call upon some knowledge of grapheme-phoneme correspondences to select the pseudohomophone. Thus, although her preferred strategy was to respond on the basis of visual similarity, even when this strategy could not be relied upon (i.e., when both al-

TABLE 3
PERCENTAGE CORRECT RESPONSES FOR WORD-
PSEUDOHOMOPHONE TASK AS A FUNCTION OF
VISUAL SIMILARITY OF NONWORD
CHOICES TO WORD

Distractor	Pseudohomophone	
	Similar	Dissimilar
Similar	63	34
Dissimilar	94	88

ternatives were similar to the word), V.S. was not totally unable to derive sound from print nonlexically. Furthermore, when unable to use visual similarity as the basis for her choice, V.S. was apparently able to employ some minimal knowledge of grapheme-phoneme correspondences for both vowels and consonants. In fact, she made more errors on trials in which the distractor item included an inappropriate or extraneous consonant than on those in which the distractor contained inappropriate vowels.

It may, therefore, be the case that V.S. could execute some minimal grapheme-phoneme conversion, perhaps at the level of single letters or bigrams, but was unable to combine a group of such phonological codes into the type of representation necessary for pronunciation of a nonword. V.S. was therefore given a phoneme-grapheme same/different task to assess her ability to associate sounds with bigrams. The printed stimuli consisted of each of the six stop consonants paired with the letter "a." On a given trial, V.S. was shown a card on which one of these six syllables was printed and was asked to judge whether the syllable pronounced by the experimenter was the same as the one represented on the card (distractors were always one of the other stop consonant + "a" syllables). Overall performance was only 75% correct, with nearly two-thirds of the errors being false positives. However, no particular pattern of confusions (such as failure to discriminate on the basis of voicing) was observed. It therefore seems that V.S.'s ability to associate sounds with letters is very poor, although not entirely lost.

In contrast to her grapheme-phoneme conversion ability, V.S.'s acoustic-phonemic conversion ability appears to be well preserved. When asked to judge whether two auditorily presented words rhymed, V.S. performed perfectly. Even when the difficulty of the task was increased by asking her to judge whether all the items in a three word set rhymed, V.S. made only 1 error in 33 trials. However, when asked to judge whether visually presented words rhymed, V.S.'s performance was so poor and so upsetting to her that the task was abandoned.

Finally, V.S. has no difficulty with repetition of single words other than the articulatory problem which is apparent in all tasks requiring verbal response. With this articulatory difficulty in mind, the list of words and nonwords for repetition was constructed of equal numbers of one and two syllable, high and low frequency, concrete and abstract nouns, functors (with the exception of low frequency one syllable functors, of which very few exist), and nonwords of one and two syllables. Examination of the results of this test, given in Table 4, reveals neither a part-of-speech nor an abstractness effect. There is a strong syllable length effect as well as a familiarity effect, with high frequency words being repeated better than low frequency words, and nonwords repeated worst of all.

TABLE 4
PERCENTAGE CORRECT REPETITION OF WORDS AND NONWORDS

Syllables: Frequency:	One		Two	
	High	Low	High	Low
Concrete nouns	100	60	60	50
Abstract nouns	90	100	50	50
Functors	100	<i>a</i>	30	0
Nonwords		60		30

^a No one syllable low frequency functors were included in this test.

These results, taken as a whole, indicate that V.S. has no difficulty with conversion of acoustic information to phonological codes, but is unable to perform the parallel conversion on visual material. This suggests that either (a) there are two separate phonological processing systems, one for visual input and one for auditory input and only the visual system is impaired in V.S. or (b) there is only one phonological processing system, with two separate input channels, with the visual input channel impaired in V.S. These alternatives are, at this time, empirically indistinguishable and further discussion of them will be deferred until relevant information becomes available.

COMPREHENSION OF WRITTEN AND SPOKEN WORDS

The Peabody Picture Vocabulary Test (PPVT) was used to assess V.S.'s comprehension of words. Form b of the PPVT was administered twice, once with visual presentation of target words and once with auditory presentation of the same target words. Since the visual test was expected to be more difficult, it was administered first, and a month elapsed before administration of the auditory test. With visual presentation, V.S. attained a raw score of 117, corresponding to an IQ of 107, or a percentile score of 66. Raw score for the auditory test was 132, corresponding to an IQ of 122, or a percentile score of 91. All but two of the nine items missed on the auditory version had been missed on the visual test.

The target words from Form b of the PPVT were later given to V.S. for oral reading. She was able to correctly read only 38 of the 150 words, producing 19 semantic errors, 14 visual errors, and 7 derivational errors. Most other errors were articulatory; only nine errors involved the production of an (apparently) unrelated word (e.g., quiescent → "sweet"). Of the items which were missed in both the visual and auditory versions of the vocabulary test, only one, "ingenious," was read correctly. It is interesting to note that to select the appropriate picture for this item, one must be able to read the word "quarantine," depicted on a sign in the picture. Thus, it is possible that V.S. was able to comprehend the

word "ingenious," and was therefore able to read it aloud, but was unable to select the correct picture on either version of the vocabulary test because she was unable to read the critical word in the picture.

WRITING

Written Naming

Perhaps because of her articulatory difficulties, V.S. prefers to give written rather than oral responses whenever possible. Since we were, in fact, interested in her writing performance, she was permitted to give written responses in tests requiring that she provide the name of a pictured or presented item. The picture naming task included eight pictures from each of nine categories: vehicles, furniture and household objects, clothing, food, common objects, people (or occupations), places, animals, and actions. For this task, V.S. gave written responses to each of the pictures in addition to attempting to respond orally. Overall, she was able to provide an appropriate label for 85% of the pictures. Seven of the eleven written error responses (spoken errors were not counted against her if the written response was correct) were semantically related to the pictured item and one of these written errors was accompanied by pronunciation of the correct word (i.e., while saying "cutting," the patient wrote "scrisor" (*sic*) and "paper"). In addition, there were several instances in which written semantic errors were immediately self-corrected, and one case in which a correct written response was immediately followed by a semantic error (shown a picture of a sofa, V.S. wrote "sofa" and then "cushion" which she repeatedly read as "couch"). Several of the "spelling" errors produced were words that were visually similar to the appropriate name; twice she wrote another word while saying the correct word, with no apparent awareness of the written error. Finally, there were two curious spelling errors. Shown a picture of a person eating a meal, V.S. wrote the letter "a," then said "eating" while writing "e_ting". Also, when shown a picture of a bowl of alphabet soup, she wrote "alph_let". This type of error, which we call a "gap" error, was produced in other writing tasks as well.

A test of tactile naming ability was devised using 59 common objects. These objects were placed one at a time in a box into which the patient would reach to hold the unseen object. Once again, V.S. was permitted to give written rather than oral responses if she so desired. Since both oral and written responses were often produced for a single object, a total of 22 written responses and 53 oral responses were produced. She was able to provide appropriate names for 43 (73%) of the presented objects; of these 43, 7 had to be seen before they could be named. We have considered an object to be "identified" when V.S. was able to express in some way (e.g., pantomime) that she knew what the object was. "Naming," on the other hand, requires that she either pronounce

or write the name of the presented object. Given these criteria, there was only one object which could not be identified even with visual presentation, and three objects whose forms were incomprehensible when held without being seen. Error responses were almost all semantically or functionally related to the presented object, but many involved spelling errors as well. For example, when handed a spool of thread, V.S. wrote "needle," "rayon," and "cotton"; when the thread was then shown to her she wrote "threak" and then "threat." The names of the objects presented in this test were later given to V.S. for oral reading, along with 36 filler items, all of which were function words. She was able to read 42 of the object names and 13 of the functors; however, the items read correctly did not always correspond to those she was able to name. Since she was permitted to give written responses on the naming test, her articulatory difficulties were not a factor in performance on that test, however, articulation did contribute to her ability to respond on the oral reading test. Of the 17 errors in reading object names 5 were clearly articulatory, and 4 other error responses were other words which bore no apparent semantic or visual relation to the target word.

Writing to Dictation

V.S.'s responses in tests of writing 96 single words and 10 nonwords to dictation showed the expected deep dyslexic pattern of errors. Errors were more likely to occur on functors than on other real words and error responses to functors were usually other functors. In addition, abstract words were more likely to elicit errors than concrete words and nonwords were never written correctly. Semantic errors are also produced in writing to dictation. For example:

<i>sentence</i>	→	<i>trial</i>	<i>frighten</i>	→	<i>afraid</i>
<i>argument</i>	→	<i>fight</i>	<i>trouble</i>	→	<i>terrible</i>
<i>mint</i>	→	<i>money</i>	<i>energy</i>	→	<i>streng_h</i>

Examples of the types of spelling errors V.S. produced in writing to dictation are shown in Table 5. The "gap" errors mentioned above are also seen in writing to dictation. Approximately 30% of the nonsemantic errors produced in writing to dictation involved omission of one or more letters, usually from the internal portion of the word and occasionally from the end, but only once at the beginning of a word, and in more than half of these omission errors a space was left for the omitted letter(s). The most frequent form of nonsemantic error involves substitution of one letter for another. These letter substitutions almost always involve letters which are visually similar (in lowercase script). For example, "n" is substituted for "r" and vice versa, "l" is substituted for "e," "b," and "t," and "w" is substituted for "u." Less frequently occurring error

TABLE 5
 EXAMPLES OF SPELLING ERRORS PRODUCED IN WRITING TO DICTATION

Substitutions		Transpositions	
language	→ languate	problem	→ promple
ground	→ groud	doughnut	→ doughnton
warrior	→ warrion	piano	→ paion, paino
squeeze	→ squeege	diary	→ dairy
stretch	→ strelch		
Omissions		Additions	
forward	→ forard	country	→ countriy
circle	→ cicle	thumb	→ thrumb
tractor	→ tracto	animal	→ animal
length	→ leng h	mouse	→ mounse
vitamin	→ vitain	torch	→ storch

types are letter additions (approximately 11% of the errors) and transposition errors (5% of the errors). Transposition errors occur most often on vowel digraphs (e.g., "piano" → "paino") but also involve consonants (e.g., "doughnut" → "doughnton"). On a few occasions words were written correctly but from right to left across the page, so that although the last letter was actually the first letter written on the page, the final string looked correct.

Since many of the spelling errors V.S. produced in spontaneous writing and writing to dictation, such as the substitution of visually similar letters and the production of "gap" errors, suggested that she might be attempting, albeit unsuccessfully, to "read off" letters from a visual/orthographic representation for the word, the question arose as to whether the representations themselves might be at fault. A lexical decision task was therefore designed in which her own spelling errors served as nonword foils (for the purpose of this test, gap errors were closed). V.S. made only 7 errors on the 75 spelling error nonwords included in this test. Since she could evidently distinguish between her own spelling errors and real words, we wondered whether she had access to specific information regarding the way in which her errors differed from the real words they were produced for, or if she were merely performing well on the lexical decision task because her errors did not correspond to existing entries in her lexicon. The 75 nonwords from the lexical decision task were divided into three groups of 25. The first 25 were presented to her with the instructions that they were misspelled words which she should try to correct. V.S. was able to correct 22 of these misspellings (although she was not satisfied with either of her attempts to correct "emergy," "every," and "emery"; the word she was trying for was "energy") and could locate the error in 2 additional misspellings, although she was unable to correct them. The second set of misspellings were presented

with the error underlined and the same set of instructions. Of these she was able to correct 19 and 1 of the 6 she was unable to correct was “fanous,” which she rewrote as “famouse.” An additional cue was presented with the third set of misspellings; the target word for each item was read aloud to her as the item was presented. She was able to correct 16 of these, and 2 of her errors consisted of correct spellings of nontarget words. For “minte” (target: “minute”), she wrote “mint” and for “promple” (target: “problem”), she wrote “probable.” V.S.’s ability to correct these misspelled items far exceeded her ability to write them correctly either spontaneously or to dictation. Her ability to correct 76% of her original 75 writing errors in these tasks indicates that she has access to intact orthographic representations of these words and that her inability to write these words correctly must be due to a breakdown in the process(es) involved in translating these representations to a form which is usable for writing.

Copying from Memory

Unlike tests of written naming or writing to dictation, tests of copying from memory, in which the printed word is shown to the patient until she feels confident that she can remember it and then taken away before the patient is allowed to start writing, showed no part-of-speech or abstractness effect. Copying from memory also differs from writing to dictation in that no semantic errors or functor substitutions are produced. Once again, letter substitutions are the most frequent type of spelling error and although omissions do occur, no “gaps” are left for the missing letters. However, a correct response to the word “mercantile” actually involved a gap which was spontaneously filled; the letters “merc” were written first and followed by a space, then the letters “tile” were written, and finally, the letters “an” were written in the space which had been left for them. Insertions and transpositions of letters are also produced in copying from memory.

Although copying from memory appears to be analogous to repetition, in the sense that no lexical effects are apparent, V.S. is not performing this task strictly by copying graphic forms from a purely visual memory store. When items to be copied are printed in mixed upper- and lowercase letters, V.S. writes all her responses in lowercase script and her responses are equal in accuracy to those produced for lowercase printed strings. Thus, she must be converting the visually presented material into some sort of abstract orthographic code which includes letter-specific information. Furthermore, although accuracy does not differ between mixed case items and lowercase items, responses are in each case affected by the “wordness” of the items; words (86% correct) are written more accurately than nonwords (42% correct). However, it is unlikely that this difference reflects lexical mediation, since none of the symptoms of deep dyslexia

are apparent in this task. In addition, this word advantage was eliminated in a second copying-from-memory task in which all stimuli were presented in lowercase print. On this test, performance on words (63% correct) was not appreciably better than performance on nonwords (57% correct). The greater difficulty V.S. had in copying words in this task may have resulted from the inclusion of considerably longer words (mean length 8.4 letters) than those used in the mixed case task (mean length 5.6). Since increasing the word length can apparently serve to eliminate the word advantage, it is unlikely to be due to the use of lexical mediation. Rather, we believe that the better performance seen with words in the mixed case task reflects an effect of familiarity, perhaps of orthographic patterns, which could facilitate graphemic encoding and/or retention in the absence of lexical access.

DISCUSSION

This patient exhibits the typical pattern of deep dyslexic errors in oral reading, written and oral naming, and writing to dictation. Semantic, derivational, and visual errors are produced in all these tasks and functor substitutions are produced in writing to dictation as well as in oral reading. In addition, both abstractness and part-of-speech effects are observed in these tasks. However, neither the deep dyslexic error types nor the part-of-speech or abstractness effects are seen in either copying visually presented words from memory or single word repetition. Familiarity, as realized in the effects of frequency and lexicality, affects both repetition and copying from memory. Repetition is also affected by word length in syllables.

This patient therefore provides confirmation of our hypothesis that deep dyslexic reading will be accompanied by deep dyslexic writing and naming, even when repetition is spared. We have proposed (Nolan & Caramazza, 1982) that deep dyslexia is caused by the cooccurrence of two impairments: a disruption of the lexicon which interferes with retrieval of the appropriate lexical form for output and a disruption of grapheme-phoneme conversion which prevents the use of a nonlexical strategy for pronouncing printed strings. Since it is the lexical disruption which causes the production of semantic errors and functor substitutions, these errors are seen in all responses which require lexical mediation, that is, in oral reading and in oral and written naming. The part-of-speech and abstractness effects, also products of the lexical disruption, are similarly seen whenever lexical mediation is required. An intact phonological processing system which can be accessed by auditory input will permit the repetition of single words without lexical mediation. Thus deep dyslexic patients may, like V.S., be able to repeat single words and nonwords or, like B.L., be unable to repeat single words without lexical mediation and produce semantic errors and functor substitutions in attempting to repeat single

words in addition to exhibiting part-of-speech and abstractness effects in repetition. Although neither V.S. nor B.L. was able to use a nonlexical phoneme-grapheme conversion system for writing to dictation, it is not clear whether this inability reflects disruption of the system responsible for grapheme-phoneme conversion or results from impairment of an independent phoneme-grapheme conversion system. It therefore remains an open question whether deep dyslexic reading will necessarily be accompanied by deep dyslexic writing to dictation. However, since written naming and spontaneous writing must be lexically mediated, they will both exhibit the same pattern of errors as deep dyslexic reading. Nevertheless, the data from this patient, V.S., provide support for independent phonological processing of visual and auditory information, since she exhibits impaired grapheme-phoneme conversion in conjunction with intact acoustic-phonemic conversion, although this independence may be achieved either by separate phonological processing systems, one specialized for visual input and the other for auditory input, or by means of independent input channels to a single system.

In addition to exhibiting the defining symptoms of deep dyslexia, V.S.'s writing was characterized by the production of spelling errors which included letter transpositions, omission of letters (both with and without gaps), letter substitutions, and, less frequently, addition of letters. These spelling errors are produced in written naming, writing to dictation, and copying from memory, but not in direct copying. V.S.'s perfect performance on direct copying indicates that her writing problem is not a problem in the programming or execution of motor operations. Also, her ability to "copy" items that are printed in mixed case in her own lowercase script demonstrates that she is able to convert visually presented material into an abstract orthographic code (see Martin & Caramazza, 1982). The fact that no deep dyslexic errors or effects are observed in copying from memory suggests that this task is executed without lexical mediation.¹ Moreover, if lexical mediation were involved in copying from memory, performance on nonwords should be much worse than performance for words, since nonwords lack lexical representations. Since V.S.'s ability to copy nonwords was only slightly inferior to her ability to copy words, no evidence is available to suggest that copying from memory involved lexical mediation. Therefore, since spelling errors occur even in copying from memory, it is unlikely that spelling errors are caused by the lexical disruption which gives rise to deep dyslexic errors in writing, naming, and reading. Nor is there any evidence to suggest that spelling errors

¹ Newcombe and Marshall (1980) have reported another deep dyslexic, G.R., who, like V.S., produces deep dyslexic errors in writing to dictation but not in written recall. Although it is noted that G.R. produces spelling errors in both tasks, these errors are not described in sufficient detail to permit comparisons to be made.

result from an impoverishment of orthographic representations. V.S.'s ability to discriminate between her own spelling errors and real words in a lexical decision task indicates that she is able to access intact representations for words. Furthermore, her ability to correct many of her own spelling errors when they are later presented to her as misspelled words suggests that spelling errors do not result from an access problem but rather from a problem in output of a correct representation.

Thus, it seems that V.S.'s writing difficulties result from a breakdown which occurs fairly late in the writing process. However, efforts to pinpoint the locus of this breakdown are to some extent hampered by the lack of a well-developed or accepted model of the writing process. This subject has, until quite recently, received little attention from psychologists; consequently, the models of writing which have been proposed are still quite speculative. Writing errors, including so-called "slips of the pen" produced by competent adult spellers (Wing & Baddeley, 1980) and errors produced by poor spellers (Frith, 1980; Marcel, 1980; Morton, 1980) and dyslexic children (Seymour & Porpodas, 1980; Avakian-Whitaker & Whitaker, 1973) provide the data base for theories of writing. One type of error, that which represents a valid but incorrect translation of phoneme to grapheme, is common in the spelling errors of both adults and children but is seen only rarely in V.S.'s writing. On the other hand, V.S.'s errors do correspond to other types of errors seen in all groups. Wing and Baddeley (1980), for example, found that many "slips of the pen" occur in the medial positions of words. They comment that such errors appear to reflect a problem in read-out from a Graphemic Buffer store perhaps resulting from a kind of lateral inhibition among items held in the buffer. Some of V.S.'s errors, such as her substitutions of one letter for a visually similar letter and her omissions of letters from the middle of a string, resemble these slips of the pen produced by competent adult spellers. However, Wing and Baddeley's account of these errors provides no indication of why V.S. should produce such a large number of these errors.

Nevertheless, the concept of a grapheme buffer, in which a representation of the string to be output must be retained, may be useful in explaining V.S.'s writing errors. It is reasonable to assume that this buffer, like other forms of time-limited storage, is subject to decay of information unless the representations stored in the buffer are periodically refreshed. The types of spelling errors observed in V.S.'s writing do, in fact, resemble the kinds of errors that would be expected to result from a rapidly decaying store. Transposition errors reflect knowledge of item information with loss of ordinal position information. Omission errors reflect loss of specific item information, while gap errors indicate that ordinal position information has been retained for both the remaining letters and for the omitted letter(s). Letter substitution errors, in which the substituted letter

is visually similar to the intended letter, may reflect retention of only partial identity information or only some features of the intended letter, such as ascender or curvilinear. Thus, it may be the case that V.S. is unable to retain information in the Graphemic Buffer for a sufficient length of time to output this information correctly. Therefore, we may suppose that the mechanism or process which is normally responsible for "refreshing" information in the grapheme buffer is impaired in V.S.

Auditory-verbal short-term memory is typically of longer duration than visual short-term memory, hence, we would expect that the duration of information storage in a Graphemic Buffer would be shorter than that of a Phonemic Buffer. The longer duration of auditory-verbal short-term memory is probably due to the greater ease and efficiency with which phonologically coded material can be rehearsed (Weber & Castleman, 1970). Models of language processing often include a Response Buffer (cf. Morton, 1970) in which phonologically coded information can be held and rehearsed by means of a phonemic or articulatory loop. If, following Newcombe and Marshall (1980), we assume the existence of a Graphemic Buffer, in which orthographic information can be held for written output, it would be sensible to allow the Graphemic Buffer to interact with the Phonological Buffer in such a way that the orthographic information can be rehearsed. Figure 1 presents a schematic representation of such a system. The Graphemic Buffer receives input from the visual system via a visual-graphemic conversion process, permitting transcription from print to script or from one case to another of visually presented words and nonwords, and/or from the auditory system via a phonologic-graphemic conversion process, thus allowing dictated nonwords to be written. The Phonological Buffer receives input from the auditory system via an acoustic-phonologic conversion process, for repetition without lexical mediation, and/or from the visual system via the grapheme-phoneme conversion process, for oral reading of nonwords. In addition,

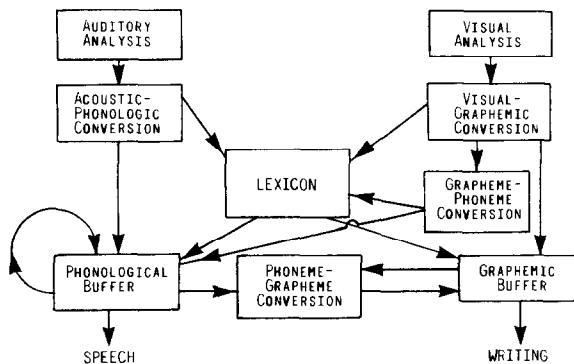


FIG. 1. A schematic model of the speech/writing production system.

each buffer can receive input from the lexicon, for the spontaneous production of oral and written language. We assume that whenever there is an output from the Lexicon to the Graphemic Buffer, there is also an output to the Response Buffer from the Lexicon. Thus, graphemic and phonemic representations for words will be available simultaneously. Finally, there is a communication system between the two buffers that permits the information in the Phonological Buffer to be translated into a graphemic code and passed on to the Graphemic Buffer. Therefore, since the information in the Phonological Buffer can be rehearsed and held for a longer period of time, this information can "refresh" the Graphemic Buffer. However, the vagaries of English orthography prohibit a direct phoneme to grapheme translation process from deriving the correct spelling for many English words. For example, Sloboda (1980) has classified English words as having either transparent or opaque spellings; transparent words are words for which a phoneme-grapheme conversion process could derive the correct spelling (e.g., *rob*) while opaque words could be spelled in several different ways (e.g., "fake" → *faik*, *fayk*, *faick*, *phake*, etc.). Thus, for the system we are proposing to function effectively, the phoneme-grapheme conversion process must have access to graphemic information which can place constraints on its alternatives. We assume, first of all, that the phoneme-grapheme conversion system is faced with several alternatives when it attempts to translate a sound such as /u/ into graphemes. So, if the word to be written is "through," the system must consult the information in the Graphemic Buffer to determine which alternative is appropriate. If, for example, the phoneme-grapheme system discovers that the string contains no "e," it will not mistakenly output the word "threw" and, if it can determine that the string ends with an "h," it will not output the nonwords "throo" or "throu." When nonwords are written to dictation, however, the Graphemic Buffer will not receive information from either the lexicon or the visual system, and the phoneme-grapheme conversion system will be free to select any of the alternative grapheme sequences which can represent the sounds of the nonwords.

If we assume that in V.S. the phoneme-grapheme system is either nonfunctional or, in some sense, "disconnected" from the Graphemic Buffer, she is left with no means of refreshing the information in this buffer. This assumption is supported by the observation that she sometimes says one word while writing another, indicating that the phonological information which is available to her for spoken output exerts no influence on her written responses. Thus, her spelling errors can be interpreted as resulting from the rapid decay of information from the Graphemic Buffer. In written naming and spontaneous writing, graphemic information is retrieved from the Lexicon and sent to the Graphemic Buffer. Sometimes, because of the lexical disruption responsible for deep dyslexic reading,

the graphemic representation for the intended word cannot be accessed and semantic errors and functor substitutions are produced. As the information in the Graphemic Buffer decays, confusions arise as to the identity and/or ordinal position of letters in the string, and in some cases this information is lost altogether, leading to omissions and gap errors. Graphemic information can also be retrieved from the Lexicon for writing words to dictation, but nonwords cannot be written to dictation because the only means of deriving a graphemic representation for a nonword, phoneme-grapheme conversion, is disrupted. The spelling errors produced in writing to dictation and written naming resemble those produced in copying from memory because in all cases the errors have a common cause, decay of information from the Graphemic Buffer. However, in copying from memory performance for words and nonwords is approximately equal because graphemic representations can be passed from the Visual-Graphemic conversion system to the Graphemic Buffer for both types of items. Finally, direct copying is intact because the Graphemic Buffer can be constantly refreshed via the Visual-Graphemic conversion system.

Morton (1980) has proposed a model of writing which is similar to the one presented here. However, information cannot be passed from the Graphemic Buffer to the phoneme-grapheme system in Morton's model, and, consequently, there is no way to insure that the correct graphemic representation derived by the phoneme-grapheme conversion system corresponds to the correct spelling of the word being written without the addition of a checking mechanism. Morton has suggested two alternative checking procedures, both of which require lexical mediation. In either case, it must first be determined that the grapheme sequence generated by the phoneme-grapheme system corresponds to a real word. Then, either the phonological representation for this word must be checked against the representation held in the Response Buffer (to prevent "known" from being written as "none") or the semantic representation of the word must be checked against the meaning of the original input. To account for the spelling errors observed in V.S.'s writing to dictation, Morton would have to postulate at least two impairments to the writing system: a disruption of phoneme-grapheme conversion and a disruption of the lexical checking mechanism. However, to account for V.S.'s writing errors within the model we have proposed, we need only assume that the phoneme-grapheme conversion process is disrupted. Consequently, once information enters the Graphemic Buffer it begins to decay rapidly and cannot be refreshed by input originating in the Phonological Buffer. Since no deep dyslexic is capable of grapheme-phoneme conversion, all such patients will be unable to obtain or use a phonological representation for visually presented nonwords and should therefore produce spelling errors in attempting to copy nonwords from visual memory. However,

if grapheme-phoneme conversion and phoneme-grapheme conversion are the responsibilities of two separate processing systems, it is possible that phoneme-grapheme conversion will be spared in some deep dyslexics. Such patients would be expected to be able to write nonwords to dictation without errors and to make only phonetic errors in writing real words to dictation. Beauvois and Derouesne's (1979) report of a patient who could write nonwords to dictation but could not read them aloud provides some support for the notion that phoneme-grapheme conversion and grapheme-phoneme conversion are independent processes.

More recently, Bub and Kertesz (1982) have reported a patient, J.C., who exhibited a writing impairment, very similar to that reported here, which they dubbed "deep agraphia." J.C.'s writing was, like V.S.'s, characterized by an inability to write nonwords to dictation, concreteness and part-of-speech effects, and the production of semantic paraphasias, while her oral reading of single words was unimpaired and nonword reading was very good (17/20 correct). Thus, while J.C. is able to apply grapheme-phoneme conversion processes, permitting her to read both real words and nonwords very well, she is unable to use phoneme-grapheme conversion to assist in written output. The lexical disruption which gives rise to "deep agraphic" writing errors is masked in oral reading by the availability of the grapheme-phoneme conversion process as a back-up system which can suppress such errors by checking the phonological representation output by the lexical system against the representation it produces. However, her inability to execute phoneme-grapheme conversion allows lexical output to go unchecked for written output. Unlike V.S., J.C. rarely produces spelling errors; omissions are the type of error most frequently produced. Nevertheless, these patients provide evidence that grapheme-phoneme and phoneme-grapheme conversion processes can be independently affected. Although it is possible to conceive of this type of dissociation in terms of a single intermodality translation system which receives input by means of two access routes which can be disrupted independently, we prefer, for the time being, to think in terms of the independent systems depicted in Fig. 1. Whether or not these conversion processes are the responsibility of a single system, the model of writing presented here, in which phoneme-grapheme conversion is an important component of the writing process, opens the door to more experimental investigations of writing. It predicts, for example, that if normal subjects are prevented from using phonological rehearsal during writing, their errors should resemble those produced by this patient. It may also provide an explanation for the frequent homophonic "slips of the pen" (e.g., "their" for "there") and other writing errors that preserve the phonological form of the intended word. If we are normally dependent on the phoneme-grapheme conversion process to maintain graphemic representations for output, it is not surprising that our writing errors are phonologically similar to the words we are trying to write.

SUMMARY

The data presented here support our earlier hypothesis that the defining symptoms of deep dyslexia will, of necessity, be duplicated in the oral and written naming of deep dyslexics. When the patient's phonological processing system is intact and can be accessed by auditory input, as it is in this patient, repetition of single words can be accomplished without lexical mediation and will not exhibit deep dyslexic errors.

The spelling errors produced by this patient in written naming, writing to dictation, and copying from memory are seen as arising from an impairment of phoneme-grapheme conversion. Thus, information in the Graphemic Buffer cannot be refreshed and decays rapidly, giving rise to errors of transposition, omission, and addition. The writing ability of other deep dyslexic patients should be investigated to determine whether this inability to convert phonemic information to graphemic codes results from impairment of a system which is specialized for phoneme-grapheme conversion or from impairment of an intermodality conversion system which is responsible for both grapheme-phoneme conversion and phoneme-grapheme conversion.

APPENDIX: WRITING ERRORS

Copying from Memory—Task 1

<u>TARGET</u>		<u>TARGET</u>	
EvER	even	ENAXTP	en tp
TEwI	tewr	SHURT	shrut
buLiT	butip	MuRseE	mutec
SPiDeR	sprider	ANMSAD	anmtar
KABEN	katen	PHARMER	phamer
RPoNt	rport	BASKET	bucket
nIsT	runt ²	THROUGH	through
daWG	dawt	RIFLE	rifte
meRphAnt	metaphant	NAHLIJ	nahiliz

² Written from right to left

Copying from Memory—Task 2

<u>TARGET</u>		<u>TARGET</u>			
amphibian	amiphite	amphides	am	highly	highy
transportation	tranitation	transitation		jinple	hinple
	trans tation			precipitation	precitative
harshly	harseby	harsiby		freckle	freckles
excavate	excated	excrated		slought	slough
concentric	concentive	concentif		ellipse	ellipce
mercantile	merc(1) an(3) tile(2)			appliance	appliance
obelisk	olesick	olesict		fecides	fecite
arthough	altrough	arthough			
sulky	súrty	surth			
tantrum	tras	trastrum			
graduated	gratition	graduate			

Written Naming³

<u>TARGET</u>			
clothespin	rope	wash	cord
	pincloth		
thread	needle	rayon	cotton
	threak	threat	
rabbit/bunny	squirrel	pump	cr
	bunny		
(alphabet)soup	alpes	soup	alph##let
	alpeslet		
belt	vest	wallel	ankle
crying	cry	cried	crying*
farm	house	barn	cournty
cutting	scrissor	paper	cutting*
garden	farmer	reap	vegetables
tractor	tracto#	tracton	tractor*
pants	w	sh	pants
plumber	wrersch	man	plumber
tying	tae	a	ti
forest/woods	wood	wond	woo
napkin	tissue	napki	
eating	a	e#ting	
pig	ho#	pig	
truck	trunk	truck	
turtle	turquio	turlle	
towels	shee	towel	
bobbypin	botl		
seashell	octo		
eyeglasses	sunglass		

³ # represents a gap; * indicates a correct response.

Writing to Dictation⁴

<u>TARGET</u>				<u>TARGET</u>		
Q tip/swab	cuticle			doughnut	doughton	do-nut
envelope	letter			engineer	machine	eigeen
clown	crow			greatly	great	greatness
toothbrush	toothb#sh			alone	only	once
nurse	nu#se			modern	model	mod
become	beue	because	became	piano	paion	paino
	becames			famous	#amous	fanous
ambulance	alm	am#lu	bu	diary	dairy	
	am#lance			vase	vace	
measure	meatine	lengh	meau	ideas	even	
	"meas" ure			down	around	
hat	hea	hit	hat*	language	languate	
gun	war	army	pit	sentence	trial	
human	hur#d	humid	humane	ground	ground	
minute	mil	mintl	minte	animal	animal	

⁴ Letters in quotation marks were provided as prompts.

Writing to Dictation—*Continued*TARGET

beautiful beau#ful
theory theo
argument fight
vitamin vitains
tuxedo tuxete
difficult s
distance n
energy strength
down dow
without outside
problem promple
frighten frign
parachute parachur
forward forard
torch storch
mountain mountair
again kind
beyond beysnd
plate plale
choose chooce
thumb thrumb
squeeze squeege
circle cicle
square sqail
blanket blancet
church chures
bicycle bicle
blanche blance
penguin pequice
secretary secrecteer
splashed sprashe
scissor scrissor
should shoold
screw skrew
mouse mounse
coffee coffle
belief beluef
spider sprider
basket backet
rifle rifte

beatiful
theo#y
r
vitaimer
tuxente
“d” ete
“d” istance
“e” n
daw
out
prolable
afraid
parach#te
forward*

beati
theory
“a” rgm
vitament
tuxede

TARGET

closely close
mint money
they we
cars car
theories theo
through under
trouble terrible
country country
answer letter
knowledge knowledge
ammonia ammorria
stretch stretch
warrior warrion
thought throught
away NA
madness NA
expect NA
restore NA

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