

## Surface Dyslexia: A Case Report and Some Theoretical Implications to Reading Models

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This paper reports on the psycholinguistic investigation of a surface dyslexic aphasic patient's abilities to handle written material. The analysis of paralexical errors produced in reading aloud single words and nonwords classically suggested that the patient was using an analytical strategy parsing the letter string stimulus, from left to right, into graphemes, and assigning phonemic values to graphemes. The patient's results were found to be sensitive to irregularities in correspondence between graphemes and phonemes not only in reading aloud but in lexical decisions, writing on dictation, rhyming, and written-word comprehension. Moreover, the patient's linguistic behavior brought out the reverse pattern observed in deep-dyslexic performances within word/nonword and content/function word dimensions. It was found that some semantic information about written words could be retrieved from both phonological and nonphonological processes presumably operating concurrently and both providing converging or conflicting pieces of meaning to the understanding of written words. Some considerations derived from the observation of this pathological reading behavior are discussed, contributing to a psycholinguistic model of normal reading.

The study of dyslexias is relevant to neuroscience from several points of view. The classification of acquired dyslexias on anatomo-clinical grounds (see, for instance, Dejerine, 1891, 1892) illustrated the contribution of such disorders to the analysis of the organization of the underlying anatomo-physiological mechanisms. The controversy on the re-

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gressive nature of linguistic impairments observed following brain damage is discussed in the studies comparing developmental and acquired dyslexias (Holmes, 1978). Psycholinguistic models, which have been developed to account for normal reading, may be good candidates to form the appropriate theoretical framework for understanding pathological behavior; the latter, in turn, provides data from which the models can be tested, revised, and improved (Davelaar, Coltheart, Besner, & Jonasson, 1978).

Analyzing, from the standpoint of psycholinguistics, the type of errors produced by dyslexic patients in reading single words aloud, Marshall and Newcombe (1973) distinguished three categories of acquired dyslexia: (i) "Visual Dyslexia" due to impaired discrimination of visually confusable letters; (ii) "Deep Dyslexia" due to an impairment of grapheme-to-phoneme conversion rules while direct access to meaning is preserved; and the reverse pattern, (iii) "Surface Dyslexia" where comprehension is mediated by grapheme-to-phoneme conversion strategies in the absence of the direct semantic route. Most of the recent studies in this field focused on deep dyslexia, this being possibly due to the particular importance of that syndrome in relation to the procedures involved in lexical comprehension. Evidence was thus found in pathology to prove the existence of a direct route from print to meaning in the normal reading system (see Patterson, 1979). Papers on surface dyslexia were (as far as we know) based on the two original patients of Marshall and Newcombe (1973, 1977; see also Holmes, 1978; and Marcel, 1980); the exceptions are Shallice and Warrington (1980), and Kremin (Note 1), who discussed two new cases.

In short, surface dyslexia in those papers is described as follows: patients make many paralexical errors in *reading single words aloud*, mostly interpretable as resulting from inadequate application of grapheme-to-phoneme conversion rules (as evidenced by errors for orthographically irregular words); no semantic errors are observed; there is an effect of part of speech and a slight effect of word length (Marshall & Newcombe, 1973; Kremin, Note 1). Other factors that might be relevant to the impaired abilities to read aloud are reported in some studies but not in others: for instance, the patients might have greater difficulty with abstract words than with concrete ones (Marshall & Newcombe, 1973); for Kremin's patient, nonwords yield fewer errors than real words; and function words are easier than content words. Surface dyslexics make few errors in *lexical-decision* tasks, but function words are better recognized than content words; and nonwords homophonic to real words may induce false recognitions (Kremin, Note 1). *Word comprehension*, as assessed by relating two items on semantic grounds in a multiple-choice paradigm, is preserved (Kremin, Note 1). When asked about the meaning of a word which has just been read aloud with a verbal paralexia,

the patients indicate the meaning of his own oral utterance ("listen" → /liston/ . . . . that boxer) instead of that of the stimulus word itself (Marshall & Newcombe, 1973). *Rhyming* should be correct in words, even between different letter string endings (Kremin, Note 1).

A classical approach to reading mechanisms (Coltheart, 1980) distinguishes, with reference to Morton's (1969) logogen system, three "routes" that are usually available when reading aloud: (i) the link between the visual logogen system (categorizing the visual information) and the output logogen system (sending phonological information to the output buffer); (ii) the intervention of the cognitive system addressed from the visual logogens and sending information to the output logogens; (iii) the route connecting visual analysis to the output buffer through grapheme-to-phoneme conversion rules. The interpretation of surface dyslexia as similar to what should be observed if the system were operating only through the latter route (the others being inoperative) may seem appropriate to account for the type of paralexical errors produced. However, as pointed out by Marcel (1980), this interpretation is questionable as concerns, namely, such effects as the part of speech or concrete/abstract dimensions, that seem to require at least some lexical involvement and should be unlikely to occur if words were to be processed in exactly the same way as nonwords.

The aim of the present paper is to report on the psycholinguistic investigation of a new case of surface dyslexia and to look for some possible reverse pattern with reference to deep dyslexic behavior. Particular attention will be devoted to the study of written-word comprehension. This observation thus contributes to the knowledge of the syndrome and, more generally, to psycholinguistic investigations of the lexicon.

### CASE REPORT

A.D., a 30-year-old right-handed man, top executive, was admitted to the Beaujon Hospital on June 15, 1978 with a severe, sudden headache and vomiting.

A CT scan showed a hemorrhage in the left ventricle and a vascular malformation in the left thalamus. A left carotid angiograph showed an arterio-venous malformation vascularized by the posterior cerebral artery, and the posterior and anterior choroidal arteries.

A left parietal craniotomy was performed on June 29, 1978. The temporal horn was approached and opened, permitting the exposure of a voluminous choroid plexus: its anterior part was normal; however, the posterior part had a voluminous angioma invading the posterior part of the thalamus (pulvinar). The whole angioma was excised after clipping all arterial feeders.

Postoperatively, A.D. had a right hemiplegia with hemisensory impairment, right hemianopsia, and aphasia. He had a slow recovery.

Six months later, when he was examined in the Service de Neuropsychologie of Professor F. Lhermitte (at the Salpêtrière Hospital), a mild right facial hemiparesis, right hemisensory impairment, and hemianopsia and aphasia were still present. There was no apraxia or agnosia. A CT scan (performed on June 29, 1979) showed a low-density lesion in the left temporal lobe corresponding to the operative scar (Fig. 1); the posterior part of the left thalamus was not easily visualized because of artifacts related to the presence of metallic clips.

In brief, at the time of the patient's aphasia examination, there were lesions in the lateral part of the left pulvinar and in the left temporal lobe, assumed to be due to operative damage.

### *Aphasia Testing*

The following aphasia examination was carried out in December 1978; the experimental investigations of the patient's abilities reported in this paper took place at this same time.

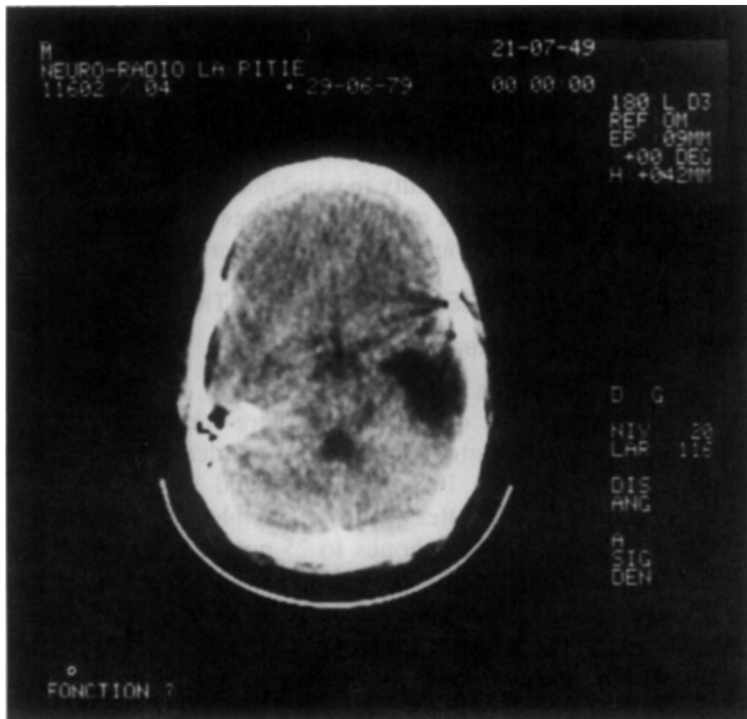


FIG. 1. A.D.'s CT Scan, left hemisphere on the right-hand side.

*Oral expression.* Spontaneous speech was fluent, correctly articulated, but restricted to short grammatical sentences with very few content words. In an object-naming task, only 2 out of 20 pictures were correctly named, there was no response to the other 18. Repetition was very disturbed; only short words, nonwords, or very short sentences could be repeated (with some phonemic paraphasias); most items, whatever their grammatical category, were not responded to. More complex linguistic tasks (word definition, narration, etc.) were poor.

*Oral understanding.* It was adequate; A.D. could designate pictures (10/10) or parts of the body and correctly carried out the most simple commands. When asked to designate two or three pictures successively or to execute multiple-step commands, he only partially succeeded.

*Writing.* Script was normal. Copying was correct. Writing words on dictation will be investigated further on in this paper. Spontaneous writing and complex writing tasks (definitions of words, narration . . .) were poor.

*Reading.* The naming of single letters, and pointing out letters when orally requested, were done correctly. A.D. could correctly associate letters or words written in different scripts or associate words to their verbal counterparts. It was possible for him to read aloud, however slowly, with phonemic paraphasias. He incorrectly matched written words to pictures. A.D.'s reading abilities are more specifically investigated in the experiments reported in this paper.

In summary, this case presents an aphasia subsequent to surgical excision of a left thalamo-choroidia angioma. This case of fluent aphasia was characterized by great difficulty in word finding, disturbed repetition, and disturbed understanding of complex sentences; the disability in reading aloud was interesting enough to merit further investigations.

## EXPERIMENTAL INVESTIGATION

### Letter Strings Read Aloud

The patient's abilities in reading single words and nonwords aloud were tested by using a list of 190 items. There were 125 words and 65 nonwords randomly distributed. The words included 65 nouns, 20 verbs, 10 adjectives, 10 pronouns, 10 prepositions, and 10 adverbs. The nonwords were pronounceable letter strings, plausible candidates for French words; 25 of them were homophones to 25 nouns in the word list. The number of letters in each individual item varied from 2 to 12 (median 6); the number of phonemes varied from 1 to 10 (median 5).

The patient's utterances were correct at the outset on 140 stimuli (74% of the cases), multiple responses with autocorrections in 35 stimuli (the final response being correct in 29 cases) and single erroneous responses in 15 stimuli.

The influence of some psycholinguistic characteristics of stimulus material on the patient's error frequency was studied.

### *Letter String Length*

There were 13% errors on short items (five letters or less) and 30% on longer ones. This significant effect ( $\chi^2(1) = 5.12, p < .05$ ) was not found when estimating the item's length by the number of phonemes. The percentage of error was the same (26%) on short items (four phonemes or less) as on longer ones. The interaction between these two factors (number of letters, number of phonemes) was not significant. The percentage of error was 24% ( $\chi^2(1) = .18, \text{n.s.}$ ) on items having as many phonemes as letters versus 27% on items having more letters than phonemes.

### *Part of Speech*

The patient experienced greater difficulty on words than on nonwords (percentages of error were, respectively, 31 and 17%,  $\chi^2(1) = 4.49, p < .05$ ), and on content words rather than on function words (error percentages, 37% and 13%, respectively;  $\chi^2(1) = 4.82, p < .05$ ). The highest error rate (43%) was observed on nouns.

### *Word Frequency*

The possible effect of this factor was tested only in the noun class (65 elements). Frequencies were found in the CNRS dictionary (1971). A median test failed to show any significant difference ( $\chi^2(1) = .15, \text{n.s.}$ ) within the range investigated (classes 300 to 3000 of that dictionary).

### *Picturability*

When requested to classify the 65 nouns according to this dimension, an agreement was obtained among students that yielded 28 picturable and 17 nonpicturable nouns. The patient seemed to meet with greater difficulties on nonpicturable than on picturable nouns (error percentages, 59 and 35%, respectively), but this tendency did not reach the level of significance ( $\chi^2(1) = 2.29$ ).

The individual responses to the 50 items in the list that were not correct are shown in Table 1. The patient's responses were transcribed in phonetics as soon as they were produced: the time interval between two stimuli being long enough to allow for the transcription. Due to some multiple responses, a total of 60 erroneous productions may be analyzed.

### *Error Analysis*

Several types of errors appeared in the patient's utterances. Almost all the reading errors occurred in noninitial position of the test words. Some, like [raisin] /Rezê/ (grape)  $\rightarrow$  /Rêzê/ can be considered as phonemic

TABLE 1  
READING ALOUD: PATIENT'S RESPONSES TO THE 50 NOT-DIRECTLY-CORRECT ITEMS

Letter string		Normal response	Patient's responses	Last response correct
mystère	(mystery)	/misteR/	/mistaR/	+
frileux	(chilly)	/fRilø/	/fRilœR/	+
cilmat	nonword	/silma/	/silima/, /kilma/	
examen	(examination)	/egzamê/	/egzamâ/	+
ouvrons	(let us open)	/uvRô/	/uvRo/	+
tiroir	(drawer)	/tiRwaR/	/tiRe/	
vous	(you)	/vu/	/mwa/, /vwa/	
pointu	(sharp)	/pwêty/	/pwa/	+
chacun	(each)	/ʃakœ/	/ʃakyn/	
poteau	(pole, post)	/poto/	/pote/	+
pagette	nonword	/paʒet/	/paget/	+
sommet	(summit)	/sɔme/	/kɔme/	+
paysan	(peasant)	/peizâ/	/pesâ/, /pezâ/	+
séjournons	nonword	/seʒuRô/	/seʒuRa/	+
mucsl	nonword	/myksl/	/myks/, /miks/	
canaye	nonword	/kanaj/	/kâ/	+
moitié	(half)	/mwatje/	/twa/	+
sicèle	nonword	/sisel/	/sikel/	
parier	(to bet)	/paRje/	/paRieR/	
hasard	(chance)	/azaR/	/asaR/	
raisin	(grape)	/Rezê/	/Rêzê/	+
méthode	(method)	/metod/	/metoʒ/	+
tiens	(you hold)	/tjê/	/tjâ/	
effort	(effort)	/efoR/	/etoR/	+
bétail	(cattle)	/betaj/	/bete/, /betel/	
acsidant	nonword	/aksidâ/	/asidâ/	+
selon	(according to)	/səlô/	/selô/	+
treize	(thirteen)	/tRez/	/tReiz/	+
tèple	nonword	/tepl/	/teple/	
caillou	(pebble)	/kaju/	/ke/, /keju/	+
amende	(penalty)	/amâd/	/ame/	+
dicsionère	nonword	/diksjonœR/	/dikse/, /diksjô/	+
mangerai	(I will eat)	/māʒRe/	/māʒe/,	+
acier	(steel)	/asje/	/akja/, /asja/,	+
passera	(will pass)	/pasRa/	/paseRa/,	+
baptême	(baptism)	/batem/	/baptem/	
réception	(reception)	/Resepsjô/	/Rekepsjô/	
vigner	nonword	/vine/	/vin/	
morceau	(piece)	/moRso/	/moRko/	
existence	(existence)	/egzistâs/	/egzistem/, /eksitâs/	
aspect	(aspect)	/aspe/	/espakt/, /ekspekt/	
counet	nonword	/kune/	/kun/,	+
refuge	(refuge)	/Røfyʒ/	/Refyʒ/	
soudain	(sudden)	/sydê/	/syde/,	+
rythme	(rhythm)	/Ritm/	/Ritem/,	+
canaille	(scoundrel)	/kanaj/	/kanel/	
regret	(regret)	/RəgR/	/RegR/	
accident	(accident)	/aksidâ/	/akidâ/,	+
pinceau	(paint-brush)	/pêso/	/pêko/	
atmosphère	(atmosphere)	/atmoʃfeR/	/akmoʃ/,	+

paraphasias with sequential error (the oral vowel /e/ was nasalized and became /ẽ/ thus creating a phonemic doublet by anticipation; see Lecours & Lhermitte, 1969). Some errors could be labelled "visual error", like in [mystère] /mistẽR/ (mystery) → /mistaR/ where the letter [ẽ], to be pronounced /ẽ/ is visually similar (that is to say deduceable through simple geometric transformations) to the letter [a], corresponding to the phoneme /a/ that was actually produced. Given an erroneous response, the error type was not always clearcut, for instance, [frileux] /fRilø/ (chilly) → /fRilœR/ could be interpreted as a visual error (letter [x] confused with letter [r]), a sequential phonemic/literal error (creation of a phoneme/letter doublet by reiteration of phoneme /R/ or letter [r]), or the result of a blend between the item to be read and the semantically related word [chaleur] /ʃalœR/ (heat). However, in the vast majority of cases, the errors listed in Table 1 seemed, in the inappropriate assigning (as regards the particular item to be read aloud) of some phonemic value to a letter substring in the item, to stem from a set of legal candidates. In French, nearly all letters have ambiguous pronunciation possibilities, the rules (if any) being determined by adjacent context (Gak, 1976). For instance, the most frequent phonemic value of the letters [c] and [s] are respectively /k/ and /s/; but when the letters appear in a vowel context, their pronunciation usually becomes [c] → /s/ and [s] → /z/. The patient's errors: [réception] /Resepjõ/ (reception) → /Rekepsjõ/ and [hasard] /azaR/ (chance) → /asaR/, are examples of disturbances in the use of such context-sensitive rules. There are some cases in French where the written unit corresponding to a phoneme is larger than one graphic letter and expands to groups of letters. The correspondence, one letter → one phoneme, no longer holds and a parser is needed to get the graphemes out of the letter string. In such instances, some ambiguities may occur in segmenting the letter string into graphemes, thus adding difficulties to converting it into a phoneme string. This is the case, for instance, in the letter substring [oin] for which two readings occur in French: (i) [oin] → /wa/ + /n/ by the application of [oi] → /wa/ and [n] → /n/ as in [moineau] → /mwano/ (sparrow); (ii) [oin] → /wẽ/ like in the word [pointu] → /pwẽty/ (sharp) (that result<sup>1</sup> from [oi] → /wa/, [in] → /ẽ/ and a deletion rule /wa/ + /ẽ/ → /wẽ/). The irrelevant application to the latter word of the first segmentation strategy may be invoked as a reason for the incorrect pronunciation [pointu] → /pwa/ by the patient. This kind of error was found in false starts: [amende] /amãd/ (penalty) → /ame/ by application of [e] → /e/ instead of [en] → /ã/. Sometimes the patient finally gave the correct pronunciation, sometimes not: [bétail] /betaj/ (cattle) → /bete/, /betel/ through [ai1] → /e/ + /1/ (by [ai] → /ẽ/ and [1] → /1/) instead of [ail] → /a/ + /j/ (by [a] → /a/ and [il] → /j/, or by any other

<sup>1</sup> This is perhaps too simple an explanation since [in] could be analyzed in another way, [in] → /i/ + /n/ by [i] → /i/ and [n] → /n/ as in [finir] → /finiR/ (to finish).



process). To this degree, the patient's utterances may suggest that he was using some primitive strategies in his attempts to read letter strings aloud. The hypothesized process might be described as a parser operating from left to right, extracting letter substrings which might be grapheme candidates, assigning phonemic values to these graphemes, and building up the response by phoneme concatenations. Such a strategy might operate on the basis of some statistical phoneme-to-grapheme knowledge (which letters or letter substrings are suitable to constitute graphemes) and grapheme-to-phoneme correspondences (which phoneme to choose among several possible readings of a given grapheme). This takes into account some recurrent errors like [c] → /k/. Nonlexical strategies of this type are clearly (at least in French and English) unable to guarantee correct utterances in all cases. Confronted with infrequent grapheme-to-phoneme correspondence the patient failed, as in [examen] /egzamē/ (examination) → /egzamā/, where /ā/, the most frequent pronunciation of [en], was uttered instead of /ē/ the correct phoneme for that word.<sup>2</sup> Some evidence of the patient's uncertainty as concerns the phonemic values to assign to graphemes can be found in his successive readings of the word [existence] /egzistās/ (existence) → /egzistēm/, /eksitās/. The two most frequent phonological values of letter [x] were tried successively: [x] → /gz/, the correct phonemes in that case and [x] → /ks/ as in [taxi] /taksi/ (taxi). Thus some lexical knowledge, dealing at least with graphemic irregularities, seems to be required for reading aloud words such as [baptême] /batēm/ (baptism), where the letter [p] is exceptionally silent. The patient sounded [p] → /p/ and produced the paralexia [baptême] → /baptēm/.

### Lexical Decision

A lexical-decision task was administered to the patient in order to assess his preserved/impaired abilities in recognizing words.

The items, 125 words and 65 nonwords, were the same as those used in the reading-aloud task reported above. Letter strings appeared on the visual display of a microcomputer under two experimental conditions, first with pattern-masking and second, the day after, without pattern-masking. The subject indicated his choice by pressing a key, either on the right or on the left of the keyboard, signifying real words and nonwords, respectively. The responses were stored in the computer memory for further analysis. A 5-sec delay occurred between the response and the next presentation. The patient was instructed to respond as fast as

<sup>2</sup> Grapheme-to-phoneme conversion rules based on regularities observed in statistical distributions, even if they took into account contextual data, should encounter some difficulties in predicting the two different readings of the ending [en] in the words [examen] /egzamē/ (examination) and [cyclamen] /siklamen/ (cyclamen) since the four last letters are the same in the two words.

he could, without trying to read aloud the letter strings. In the masking condition, the interval between the stimulus and the mask was 140 msec.

The results in Table 2, analyzed according to the word/nonword nature of the stimulus, demonstrate that the stimulus presentation condition had a differential effect on the subject's performance. Under pattern-masking, the patient's judgements were more accurate on words than on nonwords ( $\chi^2(1) = 27.17, p < .001$ ). Without pattern-masking, the results were reversed, the scores were better on nonwords than on words ( $\chi^2(1) = 11.93, p < .001$ ). As far as the word category is concerned, an effect of stimulus presentation (higher recognition scores under pattern-masking) was found for content words ( $\chi^2(1) = 6.66, p < .01$ ) and more particularly for nouns ( $\chi^2(1) = 16.52, p < .001$ ) but not for function words. The irregularities in the spelling of content words vs. function words were balanced as far as possible.

*(a) Content Words vs. Nonwords*

Within the nonwords 25 were homophones to 25 nouns in the word list. These 25 nouns differed from the other nouns in the noun class in the orthographic irregularity dimension; the 25 nonwords deduced from this noun subclass with high orthographic irregularities were constructed by replacing rare grapheme occurrences by more frequent ones. Under pattern-masking, only 14 out of the 25 orthographically irregular nouns were correctly recognized whereas the proportion rose to 34 out of 40 for nouns without orthographic irregularities. The significant effect ( $\chi^2(1) = 6.69, p < .01$ ) of orthographic irregularities on the recognition scores was absent when there was no masking, the scores being then similar

TABLE 2  
LEXICAL DECISION: ERROR RATE ACCORDING TO PART OF SPEECH AND STIMULUS  
PRESENTATION

Part of speech	Experimental condition			
	With pattern-masking		Without pattern-masking	
	Number of errors	Error rate (%)	Number of errors	Error rate (%)
Nouns	17	26	29	45
Verbs	4	20	8	40
Adjectives	4	40	5	50
Content words	25	26	42	44
Adverbs	3	30	2	20
Pronouns	0	0	0	0
Prepositions	1	10	1	10
Function words	4	13	3	10
Total words	29	23	45	36
Nonwords	40	62	8	12

between the two classes (about the same as a pure chance level). The 25 homophonic nonwords yielded false recognitions significantly more often under pattern-masking (17 out of 25) than without masking (7 out of 25;  $\chi^2(1) = 8.01$ ,  $p < .01$ ).

Some tentative hypotheses may be put forward in order to account for such data. The lexical decision process may be conceptualized as a two-stage mechanism: (i) Building up a phoneme string deduced from the letter string stimulus by application of grapheme-to-phoneme correspondence rules. That conversion should be sequential, operating from left to right and the rules should be derived from the observation of frequency regularities estimated from the subject's knowledge of language. The phoneme string thus obtained should be used in trying to enter lexicon through phonology. When a match occurred with the phonological form of a word in the lexicon, the second stage could start: (ii) checking the letter string stimulus against the written form of the word just accessed through phonology. This check might be induced by the stimuli list where 40% of nonwords were homophonic to real words. The written form may be either directly available or it may have to be computed in turn, by application, this time, of phoneme-to-grapheme conversion rules to the phonological form of the word accessed in the lexicon. If pattern-masking had occurred prior to the second stage hypothesized above, the lexical-decision strategy would be to consider any item having entered the lexicon through phonology as being a word, and deal with the other items at chance level. Such an interpretation is reinforced by the chance-level scores under pattern-masking on both nonhomophonic nonwords and on nouns with orthographic irregularities. This is also the case for the high recognition score on nouns without orthographic irregularities and the high false recognition score on homophonic nonwords.

#### *(b) Function Words vs. Content Words*

As far as such hypothetical considerations may take us, there still remains the unresolved question of function words, with which the subject experienced few difficulties, as compared to content words, particularly without pattern-masking (error rates: 10 and 44%, respectively; Yate corrected  $\chi^2(1) = 10.14$ ,  $p < .01$ ). This problem, which parallels, in the reverse sense, the deep dyslexic's behavior, will be referred to later on in the discussion.

Since stage (ii) of the lexical decision process hypothesized above referred to orthographic skills, the next section investigates the patient's abilities in writing dictated words.

#### Writing Single Words from Dictation

A list of 125 words (83 nouns and adjectives, 42 function words) was dictated to the patient. The responses were correct at the outset for 65 words (40 content words and 25 function words). For the remaining 60

words, the patient spontaneously tried to correct 13 previously incorrect responses; he was finally successful seven times. The analysis of the errors bears on the 70 erroneous responses produced. In most cases, the errors did not affect the phonological word form (the responses sounded like the stimuli but the spelling was incorrect). One or several phonemes in the stimulus (independently of their positions) had not been converted into the appropriate grapheme—relative to the particular word—but into another grapheme that sounded similar. A few examples of such errors follows: [phrase] /fRaz/ (sentence) → [frase]; [cerveau] /sɛRvo/ (brain) → [cervot]; [pourquoi] /puRkwa/ (why) → [pourcoi]; [arrêt] /aRɛ/ (stop) → [arait]; [américain] /ameRikɛ/ (american) → [amériquin]. Of the 90 individual errors found, 82 were of the spelling type defined above. The other errors were distributed as follows: four letter substitutions, probably due to phonemic substitutions, (example: [bientôt] /bjɛto/ (soon) → [vientôt] /vjɛto/); three deletions of a silent letter ([baptême] /batɛm/ (baptism) was written [batême]), and one error, [piano] /pjano/ (piano) → [piono] /pjɔno/ that could be labeled phonemic, literal, or both.

The 125 words to be written under dictation contained occurrences of 34 different phonemes. The 34 prototypical graphemic forms (i.e., the grapheme most frequently used to transcribe a given phoneme) were used together with 64 secondary forms (less frequently used, see Catach, 1973). The patient responded with 106 different graphemes: the 34 prototypes, 52 out of the 64 secondary forms, and 20 other plausible but irrelevant secondary forms. Orthographic errors were more likely to occur when phonemes had to be represented by secondary graphemic forms than by prototypical ones; the error frequencies were .40 and .04, respectively. In the former case, 43% of the erroneous choices consisted of replacing the appropriate secondary form with the standard prototype. Taken together, these results seem to indicate that this patient's orthographic difficulties cannot be restricted to a mere systematical reduction of his orthographic system since he used a larger set of grapheme forms than needed, all these forms being legal in French.

#### *Differential Processing of Function/Content Words*

Although statistically nonsignificant ( $\chi^2(1) = 1.43$ ), the patient's performances indicated a tendency to score higher on function words (60% correct) than on content words (48% correct). A further investigation of a possible relevant distinction in this stimulus dimension was conducted. Twelve nonhomographic homophones that were syntactical ambiguities were dictated to the subject. These ambiguous words were intermixed in a list containing nouns or function words. One meaning of each syntactical ambiguity was a noun, like /tRo/ meaning "trot" when written [trot], the other meaning was a function word, here /tRo/ meaning "too much" when written [trop]. In 11 out of the 12 syntactical ambiguities, the patient gave only one response and it was the function word; correctly

written in 10 cases, with a slight orthographic error in the 11th case: the omission of an accent (/tRɛ/ written [tres] instead of [très] (very) or [trait] (dash)). Out of the four possible writings of /tā/, [tant] (so much), [temps] (weather), [taon] (horsefly), [tend] (he stretches), the first three were given by the patient in that order, the third one [taon] being spelled "that fly . . . . t-a-o-n" before being actually written.

Here again, performances that seemed to be sensitive to the content/function word distinction were observed. In the case of our patient, this linguistic behavior is the reverse of that found in deep dyslexics, since his results are better on function words than on content words. A frequency effect could be invoked to account for the bias observed in our surface dyslexic patient since the function word meaning of the syntactical ambiguities was more frequent (CNRS, 1971) than that of the noun in the 11 items directly written as function words. When the frequency bias was reversed (in the item /tā/) the function word appeared first but was followed by noun forms.

As stated above, most of the paragraphic errors did not affect the phonological form of the dictated words but could be viewed as resulting from erroneous selection of a grapheme within a set of possible candidates. The next section deals with the patient's erroneous selection of phonemes.

### Rhyming

Given lists of 12 written words, the patient was asked to point to the words that did not rhyme with the first word in the list, without attempting to read aloud any word. In each list, the first noun, the ending of which defined the rhyme, was chosen in such a way that the phoneme corresponding to the reading of the last grapheme was prototypical and the grapheme was the prototypical form of that phoneme. Two lists were constructed, using respectively /ā/ and /ē/ rhymes. These two phonemes have numerous graphic correspondences, some of which overlap.

Results indicated that the patient's judgments were not based on a simple morphological strategy that would reject all words, the endings of which differed in their letter composition from the first item in the list. Several terminal graphemes ([an], [and], [ant], [en]), all sounding like /ā/ in the particular words, were recognized and grouped together. However, the grapheme [-en] was always considered as sounding like /ā/ (in accordance with reading-aloud errors), although it took the value /ē/ in some cases depending either on the previous context ([-ien] must be pronounced /-jē/) or on the knowledge of individual exceptions (the word [examen] (examination) is the only one with the ending [-men] sounding /-mē/ in French).

The patient's performances have thus been shown to be sensitive to orthographic irregularities in each of the linguistic abilities investigated

above, involving either oral/written production or lexical/phonological judgments. This linguistic behavior seems to rely heavily on the phonological aspects of the material, phonology being either directly available or deduced through conversion rules. The next section questions the possible contribution of phonology to the patient's written word understanding strategies.

### Written-Word Comprehension

As demonstrated by previous testing, the patient was unable to match written words to their corresponding pictures. His abilities to understand the written words were nevertheless investigated further in the hope of clarifying results obtained by previous researchers. Marshall and Newcombe (1973) found that comprehension might be biased by phonology since, in reading aloud, understanding concerned the oral response and not the stimulus in the case of verbal paralexias. Using a technique that did not require verbal utterance, Kremin (Note 1) found, on the contrary, that lexical comprehension was preserved. We administered to our patient an experimental paradigm devised by Albert, Yamadori, Gardner, and Howes (1973), the Odd-Word-Out Test.

#### *Experiment 1*

Given a five-word list, the patient was requested to point to the item that he felt to be semantically unrelated to the four other words (these four words being semantically related). The category name referred to by the four related items in the list was not indicated. The patient was told only that the five items were words; it was emphasized that he had to make his choice as fast as possible, without wondering whether or not he had understood or even recognized any item in the list. Comprehension of the experimental procedure was ensured by previous training through oral exercises. Immediately after the patient had responded by pointing to a word, the list was removed from his view and questions were asked by the examiner. Results are given for the 10 lists (see Appendix 1) where the patient was unable to explain his choice or recall any item on the list.

In 8 out of the 10 lists, the patient correctly pointed to the odd word. This score was significantly higher than chance level (Yate corrected  $\chi^2(1) = 5.0$ ,  $p < .05$ ) thus indicating some preserved skills for written-word processing on the semantic level, despite the patient's impaired comprehension demonstrated by his inability to match words to pictures.

#### *Experiment 2*

Words particularly liable to give rise to verbal paralexical errors due to irregularities in grapheme-to-phoneme correspondence were included in word lists submitted to the patient according to the Odd-Word-Out Test experimental paradigm. Let [chandail] /fādaj/ (sweater) be such a crucial

word. A plausible (but incorrect) pronunciation of that word could be /fâdel/, this phoneme string being obtained by the inappropriate use, in this case, of the conversion rules [ai] → /ɛ/ and [l] → /l/, or by any other mechanism. But it remains true that /fâdel/ is the correct pronunciation of a semantically unrelated word, [chandelle] /fâdel/ (candle). Such a crucial item as [chandail] (sweater) was presented in two lists of six words each. In one list, it appeared together with four words semantically related to its correct lexical meaning (clothing); in the other list, the four words were related to the meaning of the incorrect verbal paralexia induced by a phonological trap (lighting). There was a sixth word whose meaning was unrelated to both correct (lexical) and incorrect (phonologically biased) readings, i.e., clothing and lighting. The two crucial lists appeared at random in the experiment with other noncrucial six-word lists having either four or five semantically related items. The lists were presented under the same conditions as indicated above, except that the patient was told that the length of each list had been expanded from five to six words and that there may sometimes be one or two odd words in the list (oddness still being defined along semantic lines and with reference to the other items in the list).

The patient performed correctly on noncrucial lists; the results reported here bear on three crucial words (thus six crucial lists) that yielded verbal paralexias in a reading-aloud task performed independently. When asked about the meaning of the stimulus words just read aloud, the same meaning as in the oral response was reported. When questioned immediately after performing the Odd-Word-Out Test on each of the crucial lists, the patient could not explain his response. In each case (see Appendix 2), the crucial item was preserved. It thus seemed that these crucial words function, within the Odd-Word-Out Test, like lexical ambiguities: when the patient is instructed not to try to read words aloud, the written word [chandail] belongs to clothing (this is correct according to its lexical meaning "sweater") in the context of clothing items; but it belongs to lighting (and this is in accordance with its erroneous phonological reading /fâdel/ (candle)) in the context of lighting items.

It thus appeared that the surface dyslexic patient was using either (or both) semantic and phonological routes in trying to understand written words.

## DISCUSSION

### *The Psycholinguistic Investigation*

On the whole, data reported in the present study are in accordance with previous descriptions found in the literature of the surface dyslexic's linguistic behavior. Surface dyslexia was originally defined by Marshall and Newcombe (1973) with reference to the kind of paralexia errors observed in reading single words aloud. The analysis of our patient's utterances showed some confusions between visually similar letters,

some phonemic substitutions between similar phonemes, and one questionable semantic verbal paralexia (discussed later on). Most of the errors might be economically accounted for by disturbances in parsing the letter strings into graphemes and/or assigning them phonemic values out of sets of plausible candidates. In reading aloud, an effect for word length (number of letters) on the patient's performance was found, longer words proving to be more difficult than shorter ones. Picturability and frequency of use, tested only in the noun class, did not seem to have an effect. The part-of-speech dimension was shown to be a highly relevant factor, the patient experienced greater difficulties on content words than on function words, the highest error percentage occurring in the noun class. The patient's performance was also sensitive to the word/nonword dimension of letter strings, words being more likely to give rise to erroneous reading than nonwords.

The rhyming task pointed out difficulty in assigning the correct (context or lexicon dependent) phonemic value of graphemes.

The lexical-decision task indicated the influence of phonology on the process, through homophony that could induce false recognition and through orthographic irregularities that could prevent word recognition. A distinction between function words and content words emerged from the patient's performance since the two categories were differentially affected by the condition in which the stimuli were presented (pattern-masking).

Writing words from dictation showed some phonemic substitutions but, in most cases, errors did not affect the pronunciation of the words. When writing dictated homophones that were syntactically ambiguous, a bias was found toward writing the function word form instead of the content word form.

Despite severe impairment in written comprehension, as indicated by his inability to match printed words to pictures, the patient proved able (Odd-Word-Out Test) to handle some semantic processing of written words. Furthermore, phonological processes were found to compete with semantic processes in written word comprehension since words liable to elicit verbal paralexias were treated like lexical ambiguities. These items thus seemed to both encompass their standard lexical meanings and their erroneous (phonology-induced) meanings.

In short, the present investigation of a surface dyslexic patient indicates the importance of phonological strategies in handling written material and a differential effect for part of speech (and of word/non-word dimension) on performance.

### *Grapheme-to-Phoneme Conversion Rules*

These rules have been hypothesized to account for our ability to read aloud nonwords. They have been described for teaching purposes (for French, see Gak, 1976) or, in the framework of Artificial Intelligence,



for speech synthesis computer programs. Such rules are context sensitive. In French, the sounding of a letter depends in general on the letters that follow rather than on prior context. In other words, before assigning an actual phonemic value to a letter unit, the immediately following context must be considered since it may modify some preassignment. It has been shown that such forward-looking context-sensitive rules were not perfectly mastered by our patient; for instance, when he failed to soften the [c] before [e] in [morceau] /mɔRso/ (piece) → /mɔRko/. Speech-synthesis programs make use of such grapheme-to-phoneme conversion rules, but they need lists of "exception words" too. As pointed out by Smith (1975) for English, "the spelling of individual words provides insufficient information for the prediction of their sounds." The exact level of complexity of grapheme to phoneme conversion rules effectively used by (or available to) normal readers is thus not clear. It could perhaps be investigated by having normals read aloud nonwords. However, most of the psycholinguistic studies (including ours) dealing with pronounceable nonwords make use of letter strings where print-to-sound correspondence is not a problem.

### *Surface Dyslexia vs. Deep Dyslexia*

The better scores of A.D. on nonwords as compared to words and on function words as compared to content words clearly reverse the deep dyslexic performance. This clearcut behavior is crucial to any psychological theory of the lexicon. Indeed, for both A.D. and deep dyslexic patients: (i) The differential processing of function/content words is stressed since it emerges as a relevant factor even in tasks apparently unrelated to grammar like reading aloud single words, or writing syntactically ambiguous words from dictation; (ii) The ability to use strategies mainly based on phonology (such as in reading aloud nonwords) is associated with the ability to properly deal with function words. It may be convenient, in the discussion on function/content words, to recall on the one hand that when deep dyslexics make verbal paralexias they never substitute a function word for a content word, and, on the other hand that the only semantic verbal paralexia produced by our surface dyslexic patient occurred on the pronoun [vous] /vu/ (you) read /mwa/ [moi] (I). Thus the substituting word would belong to the same function word class as the stimulus. Unfortunately, the patient's response was a syntactical ambiguity! The phoneme string /mwa/ refers in French to either the pronoun [moi] (I) or to the noun [mois] (month). When asked about the meaning of /mwa/ the patient indicated, by pointing his thumb toward his chest, that he referred to himself. This is not, however, definitive evidence, as far as the comprehension of the letter string prior to utterance is concerned.

How can one link the abilities to process function words on the one hand and phonological skills on the other? In the framework of Morton's

logogen system of word recognition, the reading of nonwords aloud is assumed to be grounded on grapheme-to-phoneme conversion rules bypassing both input and output logogens. The parsing of the letter string into morphemes being relevant only for content words, input logogens should be entered only in that case, logogens having been shown to be sensitive to morphemes (Murrell & Morton, 1974). Function words, on the contrary, since they cannot be analyzed into morphemes may bypass input logogens (like the "route" using grapheme-to-phoneme conversion rules in reading aloud). This is in accordance with Bradley's (Note 2) report: "the recognition of . . . [function words] . . . is not sensitive to frequency of occurrence;" since logogens are sensitive to frequency of occurrence, function words bypass these mechanisms.

This seems difficult to reconcile with the logogen theory since if only morphemes benefit from logogen hospitality, the recognition process, which sorts these morphemes prior to entering logogens is crucial to the system—and the interest of the concept of logogen decreases.

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## APPENDIX 1

The following is a list of the words actually used in the 10 lists of the Odd-Word-Out Test (Experiment 1). The words are listed in their order of presentation, the odd item is underlined and the patient's response is written in *italics*. The words were actually presented in uppercase.

### List 1

lieutenant	(lieutenant)
capitaine	(captain)
colonel	(colonel)
<u>aliment</u>	(food)
commandant	(commander)

### List 2

Afrique	(Africa)
<u>Martine</u>	(Martha)
Asie	(Asia)
Europe	(Europe)
Amérique	(America)

### List 3

intelligence	(intelligence)
honnêteté	(honesty)
<i>sympathie</i>	(sympathy)
émotion	(emotion)
<u>tiroir</u>	(drawer)

### List 4

rectangle	(rectangle)
<u>chiffon</u>	(rag)
triangle	(triangle)
carré	(square)
cercle	(circle)

### List 6

<i>prêtre</i>	(priest)
rabin	(rabbi)
<u>placard</u>	(cupboard)
bonze	(bonze)
pasteur	(minister)

### List 7

baaignoire	(bathtub)
se doucher	(to take a shower)
<u>marteau</u>	(hammer)
bidet	(bidet)
se laver	(to wash oneself)

### List 8

Michel	(Michael)
Vincent	(Vincent)
Gérard	(Gerald)
Pierre	(Peter)
<u>crayon</u>	(pencil)

### List 9

chaise	(chair)
fauteuil	(arm-chair)
canapé	(sofa)
<u>seringue</u>	(syringe)
tabouret	(stool)

## List 5

cordonnier	(shoemaker)
menuisier	(carpenter)
<u>cendrier</u>	(ashtray)
plombier	(plumber)
teinturier	(dry cleaner)

## List 10

bleu	(blue)
vert	(green)
rouge	(red)
<u>esprit</u>	(spirit)
jaune	(yellow)

## APPENDIX 2

The following is a list of the six crucial word lists actually used in the Odd-Word-Out Test (Experiment 2) together with the three crucial words (chandail, paille, canaille) and their verbal paralexia errors (chandelle, paye, cannelle). The words are listed in their order of presentation, the totally unrelated item is underlined and the patient's response is written in italics. The words were actually presented in uppercase.

## Crucial item 1: CHANDAIL

## Lexical meaning list (sweater)

tricot	(jacket)
gilet	(waistcoat)
chandail	(sweater)
anorak	(anorak)
blouson	(golf jacket)
<u>stylo</u>	(pen)

## Verbal paralexia list/fâdel/(candle)

lampe	(lamp)
flambeau	(torch)
réverbère	(streetlamp)
<u>confiture</u>	(jam)
lustre	(chandelier)
chandail	(sweater/candle)

## Crucial item 2: PAILLE

## Lexical meaning list (straw)

tracteur	(tractor)
blé	(corn)
moisson	(harvest)
paille	(straw)
tige	(stem)
<u>projet</u>	(project)

## Verbal paralexia list/pej/(wages)

salaire	(salary)
tarif	(price list)
argent	(money)
paille	(straw/wages)
<u>bassin</u>	(pan)
prix	(price)

## Crucial item 3: CANAILLE

## Lexical meaning list (scoundrel)

crapule	(debauchee)
bandit	(bandit)
assassin	(murderer)
<u>rateau</u>	(rake)
canaille	(scoundrel)
malfaiteur	(criminal)

## Verbal paralexia list/kanel/(cinnamon)

estragon	(tarragon)
safran	(saffron)
poivre	(pepper)
canaille	(scoundrel/cinnamon)
<u>journal</u>	(newspaper)
piment	(pimento)