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The Psycholinguistic Analysis of Acquired Dyslexias: Some Illustrations

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The psycholinguistic analysis of acquired dyslexias: some illustrations

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Three approaches to the neuropsychology of cognitive function are distinguished: the *neuroanatomical* (where the primary concern is to correlate particular disorders of cognitive function with particular lesion sites), the '*general-cognitive*' (in which associations are sought between impairments of performance on specific cognitive tasks and general disorders of broadly defined cognitive processes) and the *model-building* (in which one attempts to interpret the pattern of impairments and preservations of some cognitive function produced by brain damage in terms of an explicit model of the normal operation of this function). I claim that the model-building approach to the neuropsychology of cognitive function must take precedence over the other two. One reason for this is that any disorder of cognitive function can only be defined with reference to some model of that function.

I illustrate this claim with reference to acquired disorders of reading, describing current work of a psycholinguistic nature dealing with two acquired disorders of reading: phonological dyslexia and surface dyslexia. A psycholinguistic account of normal reading is used as a theoretical framework to define and to explain the patterns of deficit and preservation observed in these two dyslexias. The detailed account of surface dyslexia in English provided by this framework is then used to make predictions about the nature of surface dyslexia in other languages: alphabetically written languages where all words are regularly spelled, or where homophones cannot occur, as well as ideographically and syllabically written languages. A case of surface dyslexia in an English–Spanish bilingual, in which such predictions were confirmed, is described.

Introduction

This Discussion Meeting is concerned with a variety of cognitive functions – visual, auditory and tactual object recognition, object naming, reading, spelling, remembering, attending, communicating by gesture, planning – and specifically with the effects upon such cognitive functions of damage to the brain. However, although this interest in the effects of brain damage upon cognitive functioning is common to all of the contributions to this meeting, the reasons for taking such an interest are varied.

At least three such reasons may be distinguished. The first of these is the *neuroanatomical*: here one's concern is with discovering which particular parts of the brain subserve which particular cognitive functions. This can, of course, be investigated directly by observing the consequences of experimental lesions (in animals) or naturally occurring brain damage (in man).

A quite different reason for interesting oneself in the effects of brain damage on cognitive functions emerges when theories are proposed concerning the role of some rather general cognitive process (such as visual perception or short-term memory) in the performance of some rather more specific task (such as reading or speech comprehension). One way of investigating such theories is to find people in whom brain damage has impaired the general

cognitive process, and to determine whether performance on the specific task is also impaired, as it should be if the general process is used in performing the specific task. This approach to the neuropsychology of cognitive function might be termed the *general-cognitive*, and is exemplified by, for example, investigating the role of planning ahead in any specific task by studying the performance on this task of patients whose frontal lesions have reduced their general ability to plan ahead.

Finally, there is the *model-building* approach. Here one begins with a specific model of some cognitive function such as remembering or reading. At least within the information-processing tradition, such models normally consist of an explicit set of processing stages with a network of pathways connecting them. One can normally predict how such a multicomponent model will behave when one of its processing stages is impaired. If the resulting abnormal behaviour of the model corresponds to any pattern of abnormal behaviour seen after brain damage, then clearly one's confidence in the model must increase, and equally clearly the model has offered an explanation of why patients with this form of brain damage perform the way they do. Thus investigations of the effects of brain damage on cognitive functioning offer ways of assessing the appropriateness of models of such functioning.

These three approaches to the neuropsychology of cognitive functioning – the neuroanatomical, the general-cognitive, and the model-building – might be thought of as independent ways of investigating a common domain. I would argue, however, that this is not so: that model building must be, and in practice often is, primary. One reason for this is straightforward. Cognitive functions such as remembering, reading or recognizing objects can no longer be thought of as unitary activities: experimental psychology has shown that functions like these must be theoretically fractionated. There are different kinds of remembering, and different stages of object recognition, for example. If one is interested in the neuroanatomical basis of memory, and one wishes to learn more about this by studying people in whom brain damage has led to a disorder of memory, a refusal to recognize that there are different kinds of memory and hence different kinds of memory disorder would surely have chaotic consequences. In practice, of course, those interested in the neuroanatomical bases of human memory do attempt to distinguish between different forms of memory disorder, but any attempt of this kind must be based upon some notion of what the different kinds of memory are – that is, upon a model of memory.

In order to expand upon this point, I shall consider a particular cognitive function, reading. The neuropsychology of reading has been investigated from each of the three viewpoints already described. For example, Benson (1979) offers a classification of acquired reading disorders that is unabashedly neuroanatomical: the categories he proposes are occipital alexia, parietal–temporal alexia and frontal alexia. The general-cognitive approach to disorders of reading is represented by, for example, the distinction that is often drawn between visual dyslexia (a disorder of reading that is a specific consequence of a general impairment of visual functioning) and auditory dyslexia (a specific consequence of a general impairment of auditory or phonological processing). This approach is also represented by those whose interest is in the role of short-term memory impairment in developmental dyslexia. Finally, the use of neuropsychological studies of reading for the development and testing of models of reading is represented by a great deal of contemporary work; numerous examples of such work can be found in Coltheart *et al.* (1980), and indeed in this paper. This particular approach is characterized by detailed psycholinguistic analysis of the reading behaviour of patients with

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reading disorders, since what the models predict is the psycholinguistic features of this behaviour: that is, predictions are made concerning which psycholinguistic properties of words will influence whether they can be read or not and which properties will have no influence upon reading. Such psycholinguistic analysis depends upon model-building, because it is the model that suggests what the relevant psycholinguistic variables will be.

The psycholinguistic analysis of reading disorders has priority over neuroanatomical and general-cognitive approaches because before one can begin to study the difference between one reading disorder and another in terms of lesion sites or associated general cognitive deficits, one must define the two disorders: this can only be done in psycholinguistic terms. Let us suppose, for example, that one could show that a reading disorder can be produced either by an occipital or by a frontal lesion, but that the characteristics of the reading behaviour were *identical* in the two cases. Would one then want to distinguish between an occipital and a frontal alexia? Clearly not. Conversely, if one could observe two psycholinguistically distinct patterns of reading disorder that could not be shown to depend upon different lesion sites, one would still want to describe these as different forms of alexia or dyslexia.

The corresponding point could be made in connection with the general-cognitive approach: only *after* psycholinguistic analysis has resulted in definitions of different forms of dyslexia does it make sense to investigate their general cognitive correlates, since if a disorder of visual perception or a disorder of auditory perception produce the same pattern of disordered reading one would not want to distinguish between 'visual dyslexia' and 'auditory dyslexia'.

Thus any investigation of reading disorders from the neuroanatomical or general-cognitive point of view must begin by saying something psycholinguistic about the patient in question. In practice, what is said is often extremely perfunctory: that the patient fails not only at reading but also at writing, for example, and hence has an alexia with agraphia. This term is still in current use by those with neuroanatomical interests, despite the fact that there are at least three utterly distinct reading disorders in all of which writing is also impaired: deep dyslexia (Coltheart *et al.* 1980), surface dyslexia (Marshall & Newcombe 1973; Coltheart 1981) and phonological dyslexia (Beauvois & Dérouesné 1979; Dérouesné & Beauvois 1979; Patterson 1982). These disorders differ from each other in terms of which psycholinguistic properties of words exert control over patients' reading and which do not.

My general claim, then, is that reading disorders (and, indeed, all language disorders) will only be understood in any depth by refined psycholinguistic analysis, and that neuroanatomical or neuropsychological investigations based upon perfunctory psycholinguistic characterization of any disorder can achieve only narrow and superficial insights. I shall attempt to illustrate this claim by discussing current psycholinguistic studies of two forms of acquired dyslexia, arguing that what has been learned about reading from psycholinguistic studies of normal readers over the past 10 years or so provides the basis for a good understanding of both these dyslexias, an understanding for which neuroanatomical or broad neuropsychological considerations are simply irrelevant. That is, one can offer convincing explanations of why these patients read as they do without referring in any way to their neuroanatomy or their general cognitive functioning. Instead, one describes a theoretical framework developed to explain normal reading. One then demonstrates how, when parts of the information-processing system embodied in this framework are impaired while the remainder of the system operates normally, the kinds of reading errors generated by the system correspond to the kinds of reading errors exhibited by dyslexic patients.

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How we read aloud: a theoretical framework

This theoretical framework may be developed initially from commonsense observations about reading. When one reflects upon the processes that might be involved in reading English aloud – in translating an orthographic into a phonological representation – it becomes obvious that, at least in principle, there are two different ways in which a reader might accomplish this task.

The first of these involves retrieving a previously learned phonological representation of the letter-string that the reader is looking at. Just as one has, at some point, learned that the spoken representation 'dog' corresponds to a certain class of visual patterns – pictures of dogs, or real dogs – so one may have learned that this spoken representation also corresponds to the letter-string *dog*. To read a word aloud by using this kind of procedure involves using the letter-string to select the correct phonological representation from among a stored set of phonological representations, each corresponding to one of the words in the speaker's written vocabulary. Since it is appropriate to refer to this set of stored word-representations as an internal lexicon, I shall refer to this method of reading aloud as the *lexical procedure*. For this procedure to be used, the desired phonological representation must pre-exist as an entry in the internal lexicon.

Our ability to read letter strings aloud is not, however, confined to those strings whose phonological representations have previously been learned and stored in an internal lexicon. We can read aloud completely novel letter strings (pronounceable non-words) whose orthographic and phonological forms have never been encountered before, and which therefore cannot exist in an internal lexicon. Whatever the procedure is that permits the reading aloud of entirely novel letter strings, it is a procedure that does not make use of an internal lexicon: I shall therefore refer to it as the *non-lexical procedure*.

The distinction between a lexical and a non-lexical procedure can thus be drawn in principle, but are there compelling reasons to suggest that this distinction is in fact applicable to the facts of reading aloud? It seems clear that there are. As I have said, one can be sure that reading aloud is not mediated solely by the lexical procedure, because if it were one would not be able to read pronounceable non-words aloud; yet one can do so. It also seems impossible to argue that reading aloud is mediated solely by the non-lexical procedure. Consider the word *pint*. It is unique among the words of English in that the *i* in the segment *int* is pronounced /aɪ/; in all other words ending *int* the *i* is pronounced /ɪ/. This is a fact specifically about the single word *pint*, a fact that needs to be learnt about this particular word if the word is to be read aloud correctly. Therefore, if one reads aloud by a procedure that does not refer to specific information about particular words – that is, one that does not refer to lexical information – then words that require reference to such specific information would be misread. No general procedure could allow one to pronounce both *mint* and *pint* correctly. I shall refer to words such as *pint* (and *sew*, *yacht*, *colonel*, etc.) as irregular words, since in such words the relations of spelling to pronunciation differ from those regularly found in English. Any non-lexical procedure for reading aloud – any procedure that makes no use of specific information about the pronunciations of particular words – will produce incorrect pronunciation for irregular words. Since we *can* read irregular words aloud correctly, we cannot be relying solely upon a non-lexical procedure to read aloud.

In sum, then, the fact that we can read non-words aloud correctly indicates that the non-

lexical procedure is used, and the fact that we can read irregular words aloud correctly indicates that the lexical procedure is used. Such elementary facts have led to the formulation of a variety of 'dual-route' models of reading (see, for example, Meyer *et al.* 1974; Coltheart 1978; Morton & Patterson 1980; Shallice 1981). What these models have in common is the postulation of lexical and non-lexical procedures for reading aloud; the models differ from each other in terms of the particular mechanisms postulated as the basis for each of the two procedures.

Evidence from acquired dyslexia

There are various results from experimental studies of normal readers that have been explained in terms of the duality of the processes involved in reading aloud, but I shall not be concerned with these here. Instead I shall be considering the application of the distinction between the lexical and non-lexical procedures to the interpretation of disorders of reading. In order to obtain, from studies of disordered reading, evidence relevant to the view that these two procedures for reading aloud do exist, one naturally seeks to discover whether a double dissociation between the two procedures can be demonstrated. In other words, does one observe a pattern of dyslexia in which the lexical procedure is relatively spared with impairment of the non-lexical procedure, and a different pattern of dyslexia in which it is the *non-lexical* procedure that is relatively spared with impairment of the *lexical* procedure?

To answer this question we must develop tests that measure the efficacy with which each of the two procedures can be used by dyslexic patients. As we have seen, the non-lexical procedure can be used to read non-words and regularly spelt words, but fails with irregular words. The lexical procedure can be used to read words (whether they are regular or irregular) but fails with non-words. Thus the tests that one uses with patients to measure the integrity of each of the two procedures will involve reading aloud three types of letter-string: regular words, irregular words and non-words. Appropriate sets of regular and irregular words were selected by Coltheart *et al.* (1979). These words were matched in pairs for number of letters, number of syllables, number of morphemes, and word frequency, and (very crudely) for concreteness, so that any difference between performance with regular words and performance with irregular words should not be due to any of these irrelevant variables, and so can be ascribed to the irregularity or regularity of a word's spelling. A dyslexic with an impairment of the lexical procedure should be worse at reading aloud the irregular words than the regular words; a dyslexic with an impairment of the non-lexical procedure should show no difference between the two types of word, and should be poor at reading non-words.

Because many dyslexics are also aphasic and may well have peripheral speech defects such as dysarthria or dyspraxia, which can complicate the scoring of tests of reading aloud, it is desirable to have a test that can measure the integrity of the lexical and the non-lexical procedures without requiring spoken responses. This may be achieved by using homophone matching as a reading task: the patient is asked to judge whether pairs of letter strings such as *sail/sale* or *sail/salt* are identical in pronunciation or not.

Three homophone-matching tasks have been devised. In the first, every letter-string shown to the patient is a regularly spelt word. In the second, there are enough irregularly spelt words for a patient operating solely by the non-lexical procedure and hence obtaining incorrect phonological representations for all the irregular words to score at a chance level (50 %). For example, two items from this second task are *ferry/fury* and *berry/bury*. A patient using only

the non-lexical procedure would respond 'different' to the first item (the correct response) but would also respond 'different' to the second item (an incorrect response) since *bury* would be phonologically encoded as if it rhymed with *fury*. Thus the patient would score 50 % on these two items, which is the chance level of performance. The third homophone matching task uses only non-word pairs such as *afe/aif* or *afe/auf*.

TABLE 1. VALUES OF d' IN HOMOPHONE-MATCHING WITH TWO VARIETIES OF ACQUIRED DYSLEXIA

(For details of A.M. see Patterson (1982).)

type of stimulus	phonological dyslexia	surface dyslexia	
	A.M.	A.B.	E.E.
regular words	3.31	1.64	1.31
irregular words	3.15	0.61	0.12
non-words	1.54	1.23	1.23

A patient with an impaired non-lexical procedure would perform well in homophone matching with words (whether regular or irregular) but poorly with non-words. A patient with an impaired lexical procedure would perform well with regular words and with non-words, and poorly with irregular words. As table 1 shows, both of these patterns of performance may be observed when patients with acquired dyslexia are tested.

A corresponding pattern is observed when oral reading is required: some patients perform very well at reading words aloud (whether they are regular or irregular) but are poor at reading non-words, while other patients are better at reading aloud with regular words or non-words than they are with irregular words.

These data indicate that investigations of acquired dyslexia do reveal a double dissociation of the two hypothetical procedures for reading aloud, and hence two psycholinguistically distinct varieties of acquired dyslexia. Impairment of the non-lexical route has been called *phonological dyslexia* (Beauvois & Dérouesné 1979; Dérouesné & Beauvois 1979; Patterson 1982), and impairment of the lexical route has been called *surface dyslexia* (Marshall & Newcombe 1973; Coltheart 1981).

The data also may be used to illustrate the reciprocity of the relation between psycholinguistics and the study of acquired dyslexia. Psycholinguistic considerations and research led to the concept of dual-route models of reading, and this concept is obviously a fruitful one when one attempts to understand the nature of phonological dyslexia and surface dyslexia. A contribution in the reverse direction – a contribution to psycholinguistic modelling from studies of acquired dyslexia – is likely to emerge soon. This stems from the fact that although, as table 1 shows, there is a double dissociation between the two procedures for reading aloud, this dissociation is not perfect. No patients have been observed in whom an impairment of the non-lexical route is accompanied by perfect operation of the lexical route; i.e. the phonological dyslexic, though very good at reading words, is not perfect. Nor have any patients been observed in whom an impairment of the lexical route is accompanied by perfect operation of the non-lexical route; i.e. the surface dyslexic, though better at reading regular words and non-words than irregular words, does make errors in reading regular words and non-words. The failures of this dissociation to be perfect may be taken to suggest some degree of non-independence of the two procedures, and it is now up to those interested

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in modelling the process of reading to explain this non-independence. This is an issue of great current interest, but it is not one that I shall pursue here.

Instead I wish from now on to concentrate on one of the two forms of dyslexia that I have been discussing: surface dyslexia. Table 2 shows results obtained from seven cases of surface dyslexia. As will be seen, in all cases regular words are read aloud with more success than irregular words; and in the homophone-matching task, performance is good with regular words or non-words and poor with irregular words.

TABLE 2. REGULARITY EFFECTS IN SURFACE DYSLEXIA (PROPORTIONS CORRECT)

(For details of R.O.G., see Shallice & Warrington (1980).)

homophone matching	M.P.	M.J.	C.D.	R.O.G.	A.B.	K.M.	E.E.
			homophone matching				
regular	0.94	0.78	0.88	—	0.78	0.68	0.74
non-word	0.98	0.74	0.78	—	0.70	0.70	0.70
irregular	0.70	0.62	0.68	—	0.60	0.54	0.52
			reading aloud				
regular	0.97	0.59	0.90	0.92	0.77	0.74	0.59
irregular	0.50	0.41	0.67	0.64	0.46	0.51	0.33

The patients R.O.G., A.B., K.M. and E.E. are all acquired dyslexics, but with various aetiologies including both stroke and head injury. It is evident, then, that aetiology is not a significant factor in acquired surface dyslexia. Table 2 also illustrates that surface dyslexia exists both as an acquired and as a developmental dyslexia: M.J. and C.D. are both developmental dyslexics, the former 10 years of age and the latter 16 years of age: neither has any history of brain damage, and both have shown very slow progress in learning to read. The initials of the seventh case, M.P., stand for 'McIlroy's Program': the reference is to a computer program for translating print to phonology, written by McIlroy (1977). This program relies almost entirely on a set of letter–sound translation rules: i.e. it uses almost entirely a non-lexical procedure. It follows that the program should exhibit the symptoms of surface dyslexia; indeed, when the program is asked to read regular and irregular words, and to perform homophone matching with regular words, irregular words and non-words, the results are characteristic of a fairly severe case of surface dyslexia.

My assertion that surface dyslexia exists as a developmental dyslexia leads to some difficult problems. Consider such extremely rare irregular words as *fleury* or *parget*. Surely virtually anyone, no matter how skilled a reader, would, when asked to read these words aloud, produce the responses /flə:ri/ and /padʒət/ respectively? Both responses are incorrect; what is more, both are regularization errors of the kind that surface dyslexics frequently make when reading aloud. This shows that, in the limit, every normal reader of English is surface dyslexic, and thus that surface dyslexia is a matter of degree, unlike other forms of acquired dyslexia, which have symptoms that would never be shown by normal readers reading under normal circumstances.

Given this argument, it is thus very likely that children whose reading is normal would perform worse with irregular than with regular words. Therefore we need to demonstrate that the regularity effects exhibited by M.J. and C.D. (see table 2) are significantly larger than those that a normal control group would show, the appropriate controls being normal

readers matched for reading age with M.J. and C.D. Such data have not yet been collected. It would also be necessary to investigate whether young normal readers also show the other two symptoms of surface dyslexia: homophone confusions in reading comprehension and phonological spelling errors. If young normal readers do display all three symptoms, we would conclude that developmental surface dyslexia consists of a failure to emerge normally from a period of reliance on phonological encoding in reading, a period through which all young normal readers pass. Evidence that young normal readers do pass through such a period has been provided by Doctor & Coltheart (1980).

Surface dyslexia in languages other than English

Surface dyslexia is regarded in theoretical terms as a selective impairment of the lexical procedure for reading aloud, with relative preservation of the non-lexical procedure; it is diagnosed by demonstrating worse performance with irregular words than with regular words. Now, of course, not all languages have irregular words, so what are we to say about how to diagnose surface dyslexia in readers of such languages? Furthermore, not all languages even allow the *possibility* of a non-lexical procedure for reading aloud, so what are we to say about whether surface dyslexia could even exist, let alone be diagnosed, in readers of such languages?

One's first thought is that surface dyslexia cannot arise in readers of languages without irregular words, nor in readers of languages where there can be no non-lexical procedure for reading aloud. Take Chinese, for example: this is written in an ideographic script, i.e. a script in which the written forms of words do not contain components that map on to components of their phonological forms. When a reader of Chinese encounters an entirely unfamiliar written form, he will be unable to read it aloud. Reading aloud thus depends entirely on having encountered the written word before; in other words, only the lexical procedure for reading aloud exists. Hence one might conclude that surface dyslexia – a sparing of the non-lexical procedure – cannot exist because there is no non-lexical procedure in the first place. This conclusion, however, is incorrect, as I shall demonstrate shortly. If we turn from ideographic scripts to alphabetic scripts, one might argue that, for alphabetically written languages that have no irregularly spelled words, surface dyslexia could not exist either.

Perhaps the most convincing way of investigating this question is to investigate dyslexia in a bilingual. Of the two languages of the bilingual dyslexic, one should possess irregular words (e.g. English or French) and the other should not (e.g. Spanish or Italian), and the dyslexia in the irregular language should specifically be surface dyslexia. Given that this stringent set of requirements is met, the reading of the dyslexic in the regular language could be investigated to decide whether surface dyslexia could exist in this language. Naturally, one could not look for a difference between regular and irregular words in the latter language, since it has no irregular words. What is necessary is to consider whether there are any *other* symptoms associated with surface dyslexia, symptoms that could be observed even in a language devoid of irregular words.

Fortunately, there are such symptoms. Surface dyslexic readers of English do not only display particular difficulties with irregular words; they often confuse a homophone with its pair when asked to define single printed words (thus defining the printed word *mown* as 'to complain', for example) and they exhibit a spelling disorder in which most spelling errors are phonologically correct (e.g. writing 'whisk' as *wisque*, or 'mayonnaise' as *mayenaze*). Even

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if a language has an entirely regular system of orthography, so that irregular words do not exist, it is still possible for homophones to exist, and still possible that a particular phonological representation can be spelled in more than one way. Therefore, in the hypothetical case of bilingual surface dyslexia now being discussed, where one language has irregular words and the other does not, the ideal case would be where the second language (the one with entirely regular spelling) contains homophones and permits phonologically correct spelling errors. An

Table 3. Surface-dyslexic errors in reading and writing English by an English–Spanish bilingual, F.E.

reading aloud

regular words: 32/39 correct
irregular words: 23/39 correct
sword → '/swɔd/'
yacht → '/jætʃ/'

defining printed words

sore → 'used to cut wood'
pane → 'to feel distress'
mown → 'to complain'

writing to dictation

'iron' → aion
'cough' → coff
'hydraulic' → highdrolic
'successful' → suxesfull

example of such a language is Spanish. Its writing system is completely regular, but the letters *b* and *v* are pronounced identically, initial *h* is not pronounced, and (at least in Latin-American Spanish) *z* and *s* have the same pronunciation, and also *c* preceding *i* or *e* is pronounced in the same way as *s*. A consequence of this is that, although Latin-American Spanish has no irregular words, it has many homophones, and phonologically correct misspellings are possible for words containing the letters *b*, *v*, *z*, *s* or *c*. So this hypothetical patient must be bilingual in English and Latin-American Spanish, and must be surface dyslexic in English. The questions of interest would then be whether he exhibits homophone confusions in reading Spanish, and phonological spelling errors in writing Spanish.

In conjunction with J. Masterson and P. Meara, I have been investigating a 25 year old English–Latin-American Spanish bilingual developmental dyslexic, F.E., who is surface dyslexic in English. Table 3 illustrates some features of his reading of English, features that illustrate why he is classified as surface dyslexic.

When his oral reading of Spanish, his first language, was tested, it was virtually perfect, for non-words as well as words: for example, he made three minor errors only in reading aloud a list of 75 Spanish non-words. Thus in oral reading of Spanish this person is not dyslexic at all – but, of course, even if he were surface dyslexic in Spanish his oral reading could be perfect, because perfect oral reading of Spanish can be accomplished by the non-lexical procedure.

We selected 21 pairs of common Spanish homophones such as *bazar* (market) and *vasar* (kitchen shelf). These 42 words were presented, singly, in printed form, in a random order, and F.E. was asked to say (in English) what each meant. In 17 cases, the correct response

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was given: for 12 of the remaining 25 words, the definition was of the homophone, for example *vasar* was defined as 'market'. Thus homophone confusions are common in F.E.'s reading of Spanish. Phonological spelling errors are also common in his writing of Spanish to dictation. Hence we have shown that F.E. is surface dyslexic in Spanish as well as English, and therefore that surface dyslexia can exist in a language that does not have irregular words. It follows that, in order to identify a language in which surface dyslexia is impossible, one must go beyond Spanish, to some language that not only lacks irregular words but in which there are no homophones, and in which alternative spellings of a single sound are impossible. An example of such a language is Italian. *None* of the symptoms of surface dyslexia can be observed in an Italian dyslexic. This is not a fact about neuroanatomical peculiarities of the Italian brain, nor about unusual cognitive processes of Italian readers: it is a fact about the Italian orthography.

In our single-case studies of developmental dyslexia the form of dyslexia observed has so far always been surface dyslexia; it would therefore be of special interest to study developmental dyslexia in Italian, since there it could not take the form of surface dyslexia. I should add here that N. Geschwind has pointed out to me that our conclusion concerning the impossibility of surface dyslexia in Italian may be false for certain dialects of Italian. There are many pairs of words in Italian that differ only in terms of whether a consonant is doubled or not: *fato* and *fatto*, for example. The doubling of a consonant is represented in the spoken form of such words, and so such word pairs are not homophonic – except in the Venetian dialect, where there is no representation in speech of the doubling of the consonant. Thus for the Venetian *fato* and *fatto* are homophones, as are the many other word pairs in Italian that differ only because of consonant doubling. Therefore Italian spoken in the Venetian dialect does contain many homophones, and hence one could in principle demonstrate surface dyslexia in Italian provided the reader spoke the Venetian dialect.

Earlier I raised the question of surface dyslexia in Chinese. Since Chinese is written in an ideographic script, only one procedure for reading aloud is possible: the lexical procedure. Thus surface dyslexia, understood as a preservation of the non-lexical procedure for reading aloud, with impairment of the lexical procedure, could not exist in readers of Chinese. On the other hand, homophones abound in Chinese, so that the orthography would allow the occurrence of an acquired dyslexia in which the dyslexic confused one printed homophone with its mate in tests of reading comprehension, and in tests of writing to dictation made homophonic errors even when the context made it clear which of two homophonic words was to be written. If it is claimed that F.E. is surface dyslexic in Spanish, the evidence being that he exhibits homophone confusions in reading comprehension and phonological errors in writing, it must therefore be conceded that a dyslexic reader of Chinese showing precisely these symptoms would count as a surface dyslexic.

This argument leads to a paradoxical conclusion: if one explains surface dyslexia as due to a preservation of the non-lexical procedure with impairment of the lexical procedure, the disorder cannot exist in Chinese; yet symptoms that justify the diagnosis of surface dyslexia can occur in Chinese readers.

Surface dyslexia as 'phonological reading'

The solution to the paradox of Chinese surface dyslexia is as follows. I have already discussed the way in which surface dyslexic readers of *English* confuse homophones in tests of reading

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comprehension, defining *sore* as 'used to cut wood' or *I* as 'I have two of them' (pointing to the eyes). The interpretation of such errors is straightforward. When the lexical procedure fails, the surface dyslexic must use the non-lexical procedure, which, when the stimulus is a homophone, will of course produce an ambiguous representation. The task of defining a printed homophone will thus become equivalent to the task of defining a *spoken* homophone, since the only representation of the printed word that the surface dyslexic can use to access his semantic knowledge is a phonological representation. There will be no means of choosing between the two members of the homophone pair, and hence sometimes an incorrect choice will be made, producing a homophone confusion in the reading–comprehension task.

In the examples given in the previous paragraph, the words were regular, and hence the phonological codes obtained by the non-lexical procedure were correct. What of irregular words? The phenomenon observed here is regularization: for example, surface dyslexic patients asked to define irregular words produce responses such as *gauge* → 'it's a big dip in the ground'. It is clear what has happened here: the lexical procedure has failed so that the non-lexical procedure must be used, and according to this procedure *au* is pronounced /ɔ/ (the regular pronunciation). Thus *gauge* is encoded as the phonological representation /gɔdʒ/; and of course this *is* a big dip in the ground. Thus both homophone confusions with regular words, and comprehension errors due to regularization with irregular words, can be understood in terms of the use of a non-lexically generated phonological representation to understand a printed word. This effect may be described as 'phonological reading', and it has an obvious interpretation in terms of impairment of the lexical procedure with preservation of the non-lexical procedure.

On this interpretation, an error that cannot occur is the homophone confusion with an irregular word. Take the irregular homophone *pear*, for example. If the lexical procedure succeeds, then this will be defined correctly, as a fruit; if the lexical procedure fails, the non-lexical procedure must be used, it will encode *pear* as /pɪə/, and the patient will define the word as something to do with close inspection. What cannot happen, on the account that I have been giving, is a response such as *pear* → 'two of them'. However, such examples do occur when surface dyslexics are asked to define irregular homophones: some instances are *bowled* → 'fierce, big'; *bury* → 'a fruit on a tree'; *piece* → 'no trouble'; *pear* → 'two of them'; *soul* → 'by yourself' and *soul* → 'bottom of something'.

In all these examples, the correct phonology of the word has obviously been accessed, but not by the non-lexical procedure (since this procedure would yield incorrect phonological representations of these irregular words). Since the definitions of the words are incorrect, these examples show that words can access their correct phonology via the lexical procedure without at the same time accessing their correct semantics. Therefore one cannot think of the lexical entry for a word as containing both its semantics and its phonology: there must be separate systems for representing semantics and phonology. Given this separation, if a surface dyslexic can sometimes access the phonological representation of a word in his lexicon while failing to access its semantic representation directly from print, he can then use the phonological representation to access semantics as if he were understanding speech. This indirect access will not permit discrimination between printed homophones, and hence homophone confusions will occur even with irregularly spelt homophones.

We may therefore distinguish between two kinds of phonological reading, both of which occur in surface dyslexia. A person who defines *pear* as 'to have a look' is reading phono-

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logically, using the non-lexical procedure to obtain a phonological representation. A person who defines *pear* as 'two of them' is also reading phonologically, but is using the lexical procedure to obtain a phonological representation.

This reasoning reveals an imprecision in the characterization of surface dyslexia adopted so far in this paper – namely the impairment of the lexical procedure with preservation of the non-lexical procedure – since the surface dyslexic error *pear* → 'two of them' illustrates correct functioning of the lexical procedure for obtaining phonology, and yet the reading response is erroneous. It is more precise to describe surface dyslexia as involving either a failure to gain access to phonology *and* semantics in the lexicon (thus forcing reliance upon the non-lexical procedure) *or* a failure to gain access to semantics in the lexicon with success in gaining access to phonology in the lexicon. It appears that each surface dyslexic reader of English that we have studied exhibits both types of failure of lexical access, i.e. both types of phonological reading, the lexical and the non-lexical.

We can now resolve the paradox of Chinese surface dyslexia. The Chinese surface dyslexic cannot exhibit non-lexical phonological reading, since no non-lexical procedure for deriving phonology from print exists in ideographic writing systems. However, provided that there are separate lexical systems for semantics and for phonology, an impairment of access from ideographic characters to semantics with preservation of access from ideographic characters to phonology would lead to the lexical form of phonological reading and hence to homophone confusions. I know of no investigations into the possible occurrence of homophone confusions in tests of reading comprehension with dyslexic readers of Chinese; thus whether surface dyslexia exists in readers of Chinese is unknown. However, the argument developed here indicates that Chinese surface dyslexia is not an intrinsically paradoxical concept, as it might seem to be on first thought.

Surface dyslexia in Japanese

The Japanese language is written in a mixture of two scripts: *kanji*, an ideographic script derived from the Chinese writing system, and *kana*, a syllabic script. Studies of acquired dyslexia in Japanese (Sasanuma 1980) reveal a double dissociation here: there are Japanese dyslexics with good reading of kanji and abolished reading of kana, whereas Sasanuma reports one case showing very poor oral reading of kanji and good oral reading of kana. Those patients with preservation of kana reading all appear to exhibit the form of acquired dyslexia known as *deep dyslexia* (Coltheart *et al.* (eds) 1980). The patient with preservation of kana reading would appear to be exhibiting the Japanese version of surface dyslexia, since an impairment of the lexical procedure for reading aloud would especially affect the reading of kanji, whereas a preserved non-lexical procedure would permit the oral reading of words written in kana.

An important feature of Sasanuma's case is that the dissociation between kanji and kana reading was confined to reading aloud; reading *comprehension*, while clearly impaired, was if anything slightly better in kanji than in kana. In this particular case, the surface-dyslexic symptomatology appears to have been produced by an anomia – i.e. a deficiency in the lexical-phonology system itself, rather than defective access from print to this system. Anomia of this kind would impair oral reading of kanji without affecting comprehension of kanji; it would also, of course, affect spontaneous speech and picture-naming; this patient did in fact exhibit anomic difficulties in both of these spheres. What is of special interest here is that

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the deficit within the lexical-phonology system that greatly impaired oral reading of kanji coexisted with almost perfect oral reading of kana. This combination of anomia with a virtually intact non-lexical procedure for reading aloud would produce, in readers of English, impaired picture-naming, spontaneous speech, and reading of irregular words with preserved reading of non-words. As far as I know, anomia with preserved reading of non-words has not been reported in any studies of English-speaking patients.

Conclusion

This discussion of phonological dyslexia and surface dyslexia has been intended to illustrate the following: if one characterizes the processes of reading, in psycholinguistic terms, as involving two different procedures for reading aloud, and if the internal lexicon mediating the lexical procedure for reading aloud is considered to include separate semantic and phonological systems, then one can account for phonological and surface dyslexias, in considerable detail, in terms of different deficits within the information-processing system used for reading. Furthermore, now that a sufficiently detailed psycholinguistic characterization of surface dyslexia in readers of English has developed, one can use this characterization to make predictions about the occurrence of surface dyslexia in other languages. In Spanish and Japanese, these predictions have been confirmed; in Chinese, it is clear what pattern of dyslexia needs to be sought, and it is also clear, from what we know about surface dyslexia in English, that surface dyslexia in Italian cannot exist. If studies of surface dyslexia in English had adopted a neuroanatomical approach, or an approach that sought to establish what general cognitive defects accompany surface dyslexia, then none of these cross-language comparisons could have been developed; nor, even if one had succeeded in establishing a consistent lesion site or a consistent set of cognitive deficits associated with surface dyslexia, would one have been any closer to understanding why the surface dyslexic reads as he does.

I conclude with a final instance illustrating the power of the psycholinguistic analysis of the dyslexias. One patient, asked to define the printed word *knows*, responded '...ah!...there's one of them just down the Old Kent Road...we used to go there on a Saturday...and there's water'. Typically aphasic semantic jargon? On the contrary: this single response is sufficient to allow one to identify not only which form of acquired dyslexia the patient was suffering from, but also which part of England he grew up in. He must be a surface dyslexic whose lexical procedure has failed with this word; hence he has encoded *knows*, via the non-lexical procedure, as /kənaʊz/. In his dialect (East End of London), that is how *canals* is pronounced; and indeed the Surrey Canal does adjoin the Old Kent Road.

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