Disorders of Reading and Their Implications for Models of Normal Reading

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Many investigators concerned with developing theoretical models of reading start from the assumption that the information-processing system used to accomplish the task of reading consists of a number of subcomponents, each responsible for performing a specific information-processing job. If this assumption is correct and if in addition the subcomponents of the system are anatomically as well as functionally separate, then one can test a multicomponent model of reading by observing the different forms which acquired reading disorder takes as a consequence of different patterns of damage to the brain. One can also use such a model to provide economical interpretations of various forms of acquired reading disorder. These possibilities are illustrated with reference to five different forms of acquired reading disorder (letter-by-letter reading, phonological dyslexia, an unnamed dyslexia, surface dyslexia, and deep dyslexia). The symptoms of each disorder are described and an assessment is made of the success with which each disorder can be explained within the theoretical framework provided by one multicomponent model of reading, a version of Morton's logogen model.

Many cognitive psychologists are currently engaged in efforts at modelling the process of reading. In some cases, their intention is to produce a detailed model of one particular aspect of reading – the identification of letters within a word, for example, or the conversion of printed letter-strings to phoneme sequences. In other cases, attempts are being made to produce a general model of the entire reading system.

Many of these investigators adopt the assumption that reading is accomplished by the use of a complex information-processing system consisting of a number of subcomponents, each responsible for performing a specific job. If one makes that assumption, then one's attempts at modelling the reading system consist of statements about what the subcomponents of this system are, and about how they are interrelated.

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After a model of the reading system has been proposed in this way, the next step is to investigate its appropriateness by experiment. There are various ways of doing this. If one's model consists of a unidimensional sequence of information-processing stages, with a unidimensional flow of information, one might devise tests of the model based upon the additive-factors technique developed by Sternberg (1969). Numerous other techniques for testing multicomponent models have been devised: for example, selective interference (Brooks, 1968) or the study of stimulus confusability effects (Conrad, 1964).

These techniques rely upon the use of experimental manipulations to try to produce predicted effects in experiments with normal readers. A completely different approach to the assessment of models of reading is to investigate abnormal readers. Studies of impaired reading can provide tests of predictions from models of the normal reading process, and models of the normal reading process are able to offer natural and economical interpretations of the various forms of abnormal reading.

Any method for testing models of reading makes its own set of assumptions – for example, use of the Sternberg additive-factors method assumes unidimensionality and unidirectionality of the sequence of information-processing stages – and the neuropsychological method is no exception. Any user of this method has to hope that any two components of the reading system which are *ex hypothesi* functionally independent are also anatomically independent in the sense that it is possible for the brain to be so damaged that either of these components can be impaired or abolished whilst the other continues to function normally. An advantage of the neuropsychological approach, however, is that if this assumption is false (e.g., if the neural mechanisms subserving functionally separate components are anatomically intertwined and so cannot be independently impaired by brain damage), the data one collects from people with reading disorders are likely to be uninterpretable within the context of one's model of reading, rather than actually misleading. In the limit, where no subcomponent can be damaged whilst any other is intact, brain damage will have a merely quantitative effect on reading, and one will not discover qualitatively different forms of acquired dyslexia. This would make it clear that the neuropsychological approach to testing multicomponent models of reading is futile.

Competent readers can perform a number of different tasks when confronted with a string of letters. Although there is no reason why these various tasks should map one-to-one on to the various subcomponents of the reading system (for example, some tasks might be performable by more than one component, and some components might be used for performing more than one task), it must be that the system as a whole is capable of performing all the tasks that we know readers can perform; if any of these tasks are beyond the capabilities of a postulated system, then the model of reading embodied in this system is at best incomplete. I begin, then, by describing what I take to be the important kinds of tasks which readers are capable of when presented with a single string of letters.

SOME READING TASKS

Abstract letter identification

One task performed with ease by the skilled reader is the identification of a letter regardless of its particular form. We all know that a, A, *A*, and a are examples of the letter A. Absence of the ability to achieve such identifications would prevent a reader from being able to read anything printed in a typeface which he has not seen before. Since unfamiliar typefaces can be read without difficulty by the skilled reader, it follows that the reading system employed by such a reader must include a component whose job it is to identify letters even when their particular visual forms have not been encountered before. I propose to call this component Letter Identification, and I suggest that what the component actually does is to assign to seen letters their appropriate Abstract Letter Identities (ALIs).

By way of illustrating what I mean by ALIs, consider an experimental task used very widely in the past fifteen years: visual same-different matching. If a subject judges that the words GARDEN and GARDEN are the same whilst the words GARDEN and DANGER are different, what account might we give of how this is achieved? We assume that each of the two stimuli are encoded, and that the decision as to the sameness or differentness of the two stimuli is made by comparing the two encodings; but what is the nature of the code employed? In the example I have just given, three possibilities often considered are:

(a) Semantic code: the response "Same" is made when the two stimuli have the same *meaning*.

(b) Phonological code: the response "Same" is made when the two stimuli have the same *pronunciation*.

(c) Visual code: the response "Same" is made when the two stimuli are *visually identical*.

Judgments that GARDEN/GARDEN requires a "Same" response and GARDEN/DANGER requires a "Different" response could thus be accomplished perfectly by using any one of these three kinds of code. Therefore, if one wishes to explore the uses of the various types of code, one needs to design stimuli in such a way that not all of the codes are usable; and this avenue of research has been extensively explored.

One can render the use of semantic codes irrelevant by using stimuli which do not possess semantic codes – namely, nonwords. Judgments concerning DENGAR/DENGAR and DENGAR/NADGER cannot use comparisons of semantic codes, and so here the experimenter has compelled the subject to use either a phonological code or a visual code.

One can then eliminate the use of a visual code by varying case. Since DENGAR and dengar are visually different, one cannot judge them to be the same by comparing their visual codes.[1]

This leaves only one code remaining: the phonological code. Thus by using nonword stimuli differing in case one has reduced the number of possible codes in the visual same/different task from three to one, the phonological code.

If one wished to restrict subjects to the use of semantic codes only, one could eliminate visual codes by using different cases, and one could eliminate phonological codes by using pairs of homophones for all the "Different" stimuli: thus responding "Same" to PHRASE/phrase and "Different" to PHRASE/frays obliges the subject to use semantic codes. Similarly, if one wishes to restrict subjects to the use of visual codes, one instructs them to respond "Same" only when stimuli are visually identical, and one uses as "Different" stimuli item pairs which differ *only* in case. Responding "Same" to GARDEN/GARDEN and "Different" to GARDEN/garden requires the use of visual codes, since for every item pair (including all the "Different" pairs) the two items have the same semantic code, and the same phonological code.

This theoretical rationale for the analysis of the codes used in visual same-different matching tasks has served as the basis for a great deal of research in the past fifteen years, beginning with the studies of visual and name codes by Posner and his associates (Posner, Boies, Eichelman, and Taylor, 1969)[2]. The rationale depends crucially on the assumption that the list of potentially usable codes I gave earlier is *exhaustive* – that is, that there are only three possible codes, so that if one eliminates two by appropriate choice of stimuli one knows exactly what form of code the subject must be employing. Studies of reading disorders, however, reveal that this assumption of exhaustiveness is false. Two examples will be given: one in connection with conduction aphasia, and the other in connection with deep dyslexia.

In conduction aphasia, the patient's speech comprehension will be at worst mildly impaired, and at best intact, and speech production will also be relatively good; in contrast there is a gross impairment in the ability to repeat stimuli which are spoken to the patient. The syndrome is reviewed by Green and Howes (1977) and by Benson, Sheremata, Bouchard, Segarra, Price, and Geschwind (1973).

The patient to whom I refer here, K. C., (see Coltheart, Wyke, and Henson, submitted) had intact speech comprehension, and intact speech production except for some word-finding difficulties; but when asked to repeat even a single short spoken common concrete noun, he sometimes was unable to do so correctly. Thus his repetition deficit was severe.

Although reading aloud of common concrete nouns was poor (15 correct out of 25), matching these to pictures was perfect. Various other tests of comprehension of single printed words were tried, and performance was uniformly error-free. Consequently, ability to access semantics from print was unimpaired, at least for the classes of words we used, whilst ability to derive articulation from print was considerably impaired (since reading aloud was defective).

A failure to read aloud could be due either to a failure to derive phonology from print, or to a failure to derive articulation from phonology. One can adjudicate between these two possibilities by using tasks which do not require articulation, but which do require the derivation of phonology from print. One such task is homophone matching: the patient is given pairs of words, and asked to judge whether the two words in a pair have identical pronunciations or not. For example, the patient should classify SO/SEW as "Same" and NO/NEW as "Different".[3] Our patient was given 50 word pairs, 25 of which were homophonic and 25 not, and asked to sort the 50 pairs into two categories (homophonic versus non-homophonic). He was correct with 16 of the 25 homophones and 16 of the 25 non-homophones; this performance (64% correct) is very poor and in fact is barely above chance ($\chi^2 = 3.92$, $\chi^2_{[.05]} = 3.84$). Thus even when overt articulation is not required, this patient's phonological processing of print is severely impaired.

Suppose one now asked him to do same/different matching of nonwords with the two items in a pair differing in case. Since these two are nonwords, semantic coding cannot be used; since their case varies, visual coding cannot be used; and since the patient's ability to match stimuli using phonological codes (homophone matching) is grossly impaired, matching using phonological coding will be almost impossible. Therefore, if these are the only three codes which are in principle usable, this patient should be near chance at same-different matching of nonwords differing in case. In fact, however, the patient performed this task with ease and entirely without error: he could respond "Same" to stimuli such as ANER/aner and "Different" to stimuli such as ANER/aneg with no difficulty.[4]

This means that the list of three codes given earlier is not exhaustive, since it is possible to respond "Same" to ANER/aner without using a phonological code. There must be at least one additional possible code. I suggest that this fourth kind of code uses the identities of the letters – *abstract* identities in the sense that neither the phonological representations nor the visual forms of the letters are being used.

If it is conceded that one can judge that A and a are the same without using name codes (using ALIs instead), this has certain consequences for the interpretation of the past decade's work on visual same-different matching. For example, it has been found that Aa matching is faster in the left hemisphere than the right, whilst AA matching is faster in the right hemisphere than in the left (Geffen, Bradshaw, and Nettleton, 1972), and it has been argued that this is evidence for the superiority of the left hemisphere at phonological processing; but this inference is not legitimate if Aa matching is possible using a code which is *not* phonological (namely, the ALI code). More generally, one cannot assume that one is studying the name code in experiments involving matching of nonwords or letters differing in case.

The performance of this conduction aphasic patient in matching nonwords differing in case provides evidence for the concept of ALIs. Evidence for this concept is also provided by the performance of patients suffering from deep dyslexia (Marshall and Newcombe, 1966, 1973; Coltheart, Patterson, and Marshall, 1980). This syndrome is described in more detail later in this paper. For these patients, reading nonwords aloud is virtually impossible, and so is judging whether or not printed nonwords rhyme; however, they can read a considerable number of words aloud, especially concrete nouns, and can comprehend an even greater number. Since deep dyslexics cannot encode letter-strings phonologically prior to lexical access, their reading (silent or oral) must depend on visual coding of words. Of course, the term "visual coding" is extremely vague in this context, but one thing it might mean is the treating of words as overall visual forms, as wholistic configurations. If this is what visual coding of words means, then disrupting the visual form of a word should make reading aloud very difficult for the deep dyslexic. A powerful way of doing this is to alternate case within a word: the visual form of TrEe is entirely novel, and certainly quite unlike the visual form of TREE or tree. However, as Saffran (1980) has shown, the ability of deep dyslexics to read words aloud is not significantly reduced by presenting words in alternating case. It follows that the visual code they use is not a wholistic visual configuration; Saffran (1980) proposed that the nonphonological method of reading relies on abstract letter identities instead.

Studies of the characteristics of reading in two neuropsychological disorders – conduction aphasia and deep dyslexia – thus provide evidence for the validity of the concept of abstract letter identities. Further evidence of various kinds is provided from studies of normal skilled reading.

Scarborough, Cortese, and Scarborough (1977) showed that the "No" response to a nonword in a lexical decision task was faster if the same nonword had been presented on an earlier trial, and that this was so even if the two presentations of the nonword were in different cases. What is it that is being repeated to produce this repetition effect? It cannot be a semantic code (since the items are nonwords) nor a visual code (since the item is repeated in a visually different form); perhaps it is a phonological code. If so, nonword homophones should show a facilitation effect: the "No" response to FLANE should be facilitated by prior presentation of PHLAIN. Davelaar (unpublished experiments, University of Reading), however, has shown that no facilitation is obtained in this situation. This suggests that the crucial factor is the repetition of a particular sequence of ALIs, since neither semantic nor visual nor phonological repetition is sufficient to explain the effect.

Rayner, McConkie, and Zola (1980) presented single target words in parafoveal vision, and requested subjects to make a saccadic eye movement to the target word and then to read the word aloud. Changing the case of the target word during the eye movement had no effect on naming latency, whereas replacing the word with a different word slowed the naming response. These results are compatible with the view that information about ALIs is collected prior to the initiation of the saccade, and that if this information remains pertinent (i. e., if the *identities* of the letters in the target word are not changed during the saccade) this facilitates processing of the target word after the saccade.

Evett and Humphreys (in press) showed that tachistoscopic report of single words was facilitated by prior presentation of nonwords sharing letters in the same position, even though the nonwords were in lowercase and the words were in uppercase (e. g., the report of the word WHITE was better when it was preceded by whibe than when it was preceded by sornd). They proposed that this result should be explained in terms of priming of ALIs: assigning an ALI to the first letter in WHITE is facilitated by prior presentation of a letter string in which the first letter has the same ALI.

Although the various lines of evidence just cited provide a variety of forms of support for the ALI concept, the precise role played by ALIs in the processing of words is by no means clear. The simplest proposal is that the first stage in word processing is the assignment of ALIs to each of the letters in the word, and that subsequent stages use these ALIs as data. This proposal is contradicted by several findings. Firstly, it is not evident why, if this proposal were correct, tachistoscopic report should be worse for case-alternated words like GaRdEnEr than for GARDENER or gardener; this impairment is small, but it exists (Coltheart and Freeman, 1974). Why should the assignment of ALIs be more difficult for case-alternated stimuli? But if it is not, then no effect of case alternation could occur, since once ALIs are assigned lettercase is irrelevant. Secondly, Henderson and Chard (1976) have shown that, in same-different matching, the "word"-superiority effect enjoyed by acronyms such as FBI in comparison with control stimuli such as BFI does not occur when the acronym is presented in the wrong case; and Besner (1980) has shown that precisely the same is true when the task is tachistoscopic report. Thirdly, McClelland (1977) showed that subjects taught arbitrary meanings for nonwords presented in uppercase were slower at subsequently accessing these meanings when the nonwords were presented in script, and vice versa (although this difference disappeared with practice).

These results are, of course, not *inconsistent* with the concept of ALIs. They simply require one to suppose that ALI coding is not the only way in which print is represented at the early stages of the reading system. The fact that semantic information necessary for reading comprehension sometimes depends upon case or some other aspect of typography is sufficient to indicate that specific visual information is preserved during reading rather than being discarded at the first stage.

It is thus evident that at present we are unable to give a complete account of the role played by ALIs in reading. Nevertheless, the evidence cited above does indicate that readers are *capable* of abstract letter identification and do perform this task during reading. Therefore one must attempt to include in one's model of reading a subcomponent capable of performing the task.

Word recognition

What I mean by "word recognition" is determining that a particular sequence of letters is a word which one has seen previously and which one is seeing again (re-cognising) now. One studies this process of word recognition by presenting a subject with strings of letters, some of which are words and some nonwords, and requiring him to decide which are words and which are not: this is known as the lexical decision task.

Lexical decisions can be performed with remarkable speed. Typical mean latencies for deciding that a letter string is a word are around 500 msec. Since a portion of this time is attributable to peripheral input and output processes, it is evident that the time needed to consult one's stored knowledge about words and to decide that a letter string is a word is at most only a few hundred milliseconds.

An important point here concerns the nature of the nonwords in lexical decision tasks. If the nonwords are all inconsistent with the orthographic constraints of English if they are sequences such as QVBLO or SKRPJ – it is in principle possible to make accurate "Yes" and "No" decisions simply by determining whether a letter string is orthographically regular or not. In this case, the lexical decision task does not require the subject to consult an internal lexicon. However, if (as is usually the case) all nonwords are orthographically regular sequences such as LEAT or MAINTINESS, the subject is forced to consult his internal store of words. How else could he determine that such items as these are not actually words?

It follows that the normal reading system must include a subcomponent which is capable of interrogating the reader's knowledge of all the words in his vocabulary so as to determine whether any of these words matches the stimulus letter string; and that such interrogations can be completed extremely rapidly.

Word comprehension

Words have meanings, and readers can discover these. Thus the reading system is capable of accessing, from a printed representation, a semantic representation which is the meaning of the word the reader is looking at; and hence the system must possess a subcomponent which accomplishes such access.

Word pronunciation

It is also possible for readers to read words aloud, and hence they are able to access a phonological representation from a printed word. The reading system must therefore contain a subcomponent capable of this task.

Nonword pronunciation

Reading aloud can be achieved successfully with letter strings even when they are not words. As will be discussed later, in some forms of reading disorder nonword reading is much more seriously impaired than word reading, which suggests that we should be prepared to regard these two tasks as different ones. Furthermore, as is also discussed later, many models of normal reading postulate that there are two different ways of reading aloud: one of these ways is available only when the letter string is a word, and the other way is usable for all nonwords but not for certain types of words.

The concept of two routes to pronunciation may turn out to be wrong, and it may be the case that the same mechanism is used for reading words and nonwords aloud; but it is clearly necessary at present to distinguish the two tasks (reading words aloud and reading nonwords aloud), and to require any postulated reading system to include a subcomponent capable of reading nonwords aloud as well as a subcomponent capable of reading words aloud. At the same time, one must keep in mind the question of whether it is the same subcomponent which performs these two tasks, or whether there are two different subcomponents involved.

Implications for models of reading

I have just described a number of tasks which the normal reader can perform when confronted with a letter-string. He can assign abstract letter identities to the letters; he can recognise whether the letter-string is a word of English or not; if the letter string is a word, he can understand what it means; and whether it is a word or not, he can read it aloud. Thus, whatever the cognitive system which subserves reading is, it must be capable of performing all of these tasks, and so any model of the system which aspires to completeness must provide explanations concerning how each of these tasks is performed.

The aim of this paper is to illustrate how such models can offer interpretations of, and in turn be tested by, reading data collected from patients suffering from acquired dyslexia, data gathered by requiring such patients to perform the various reading tasks just described. The next step, then, is to outline one such model; then various forms of acquired dyslexia will be described; and finally I will consider how each of these acquired dyslexias might be interpreted within the theoretical framework offered by the model.

THE READING SYSTEM: A THEORETICAL FRAMEWORK

A model for the reading aloud and the comprehension of single words is depicted in Figure 1. It is an extension of, but otherwise differs only in minor ways from, the current version of the logogen model (see e.g., Morton, 1979; Morton and Patterson, 1980). According to this diagram, the initial stage in reading is the assignment of abstract identities to the letters in the word the reader is inspecting. The output of this stage has three different uses: it serves as input to a word recognition component, to a non-lexical procedure for converting print to phonology, and to a letter-naming component. One can assess the integrity of the ALI component in a dyslexic reader by using the nonword cross-case matching task described earlier, the assumption being that the ability to judge the identity of A and a requires the correct functioning of a system which assigns abstract identities to these two letters.[5]

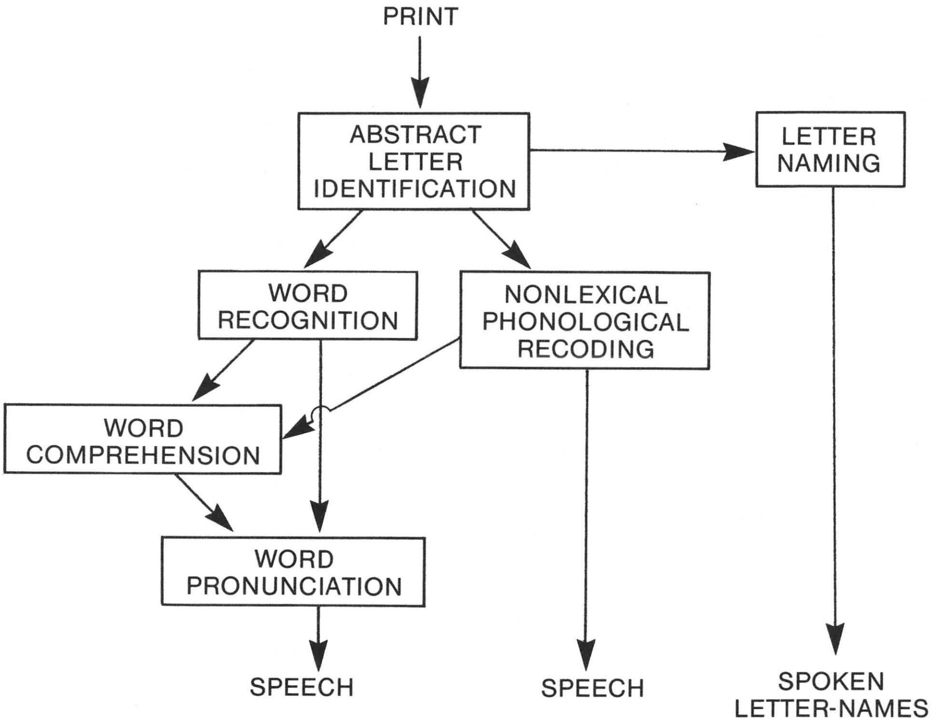

Figure 1.

The word recognition component in the diagram corresponds to the visual input logogen system in the logogen model. It contains "word detectors," one for each of the words in a person's reading vocabulary. This component responds when a word is presented, but not when a nonword is presented, and I assume that it is this differential response which permits readers to make lexical decisions.[6] If this assumption is correct, then integrity of this component may be tested by using the lexical decision task with dyslexic patients.

The comprehension component in the diagram is the system required for understanding the meanings of printed words, and its correct functioning can be assessed by having dyslexic patients perform tasks requiring such understanding: judging whether word pairs are synonymous, for example, or obeying printed instructions, or matching words to pictures.

The component labelled "word pronunciation" and the component labelled "nonlexical phonological recoding" serve the same function – they enable the reader to read aloud. Why does the model provide two different ways of performing this one task?

If the only route from print to speech were via word pronunciation, we could not read nonwords aloud, because this route proceeds via the word recognition component, and this component cannot respond to nonwords. Since we can read nonwords aloud, the model must incorporate a method for doing so.

If the only route from print to speech were via nonlexical phonological recording, it would be necessary to explain how this nonlexical process could deal correctly with the vagaries of English grapheme-phoneme relationships. This point can be elucidated only by being more precise concerning the way in which such nonlexical phonological recoding occurs. A popular proposal has been that this conversion is accomplished by grapheme-phoneme correspondence rules (GPCs): a detailed exposition of what is involved in such a proposal has been given elsewhere (Coltheart, 1978). Consider the word *down*. This contains the graphemes *d, ow,* and *n.* The most common pronunciations of these three graphemes are /d/, /aω/ and /n/. Thus if the assignments of phonemes to graphemes which are used by the GPC procedure are those which are the most common, the GPC procedure will yield *down* → /daωn/, which is correct. Most words containing the grapheme *ow* will be dealt with correctly, in fact; but not all, since *mown* → /maωn/ is incorrect. For this reason, words like *mown* have been known as irregular or exception words, and the view has been taken that nonlexical conversion of print to phonology, if it uses GPCs, will only function correctly for regular words (and nonwords). As we will see, there is neuropsychological support for the distinction between regular and irregular words: in the syndrome known as surface dyslexia, described below, reading aloud is much more frequently correct for regular words than for matched irregular words, and, what is more, many incorrect readings for irregular words take the form of applying GPCs to these: for example, *pint* is read as /pɩnt/, *quay* as /kweɩ/ and *bury* as /bjuri/. On this view of the nature of nonlexical conversion from print to phonology, such conversion will not work for irregular words; since *lexical* conversion of print to phonology does not work for nonwords, we therefore need to postulate two different pathways from print to speech because we are able to read nonwords and irregular words.

However, data provided by Glushko (1979) make it difficult to retain the view that nonlexical conversion of print to phonology operates by using GPCs. There are two important results in Glushko's work. Firstly, he showed that regular words like WAVE (for which there exists an "orthographic neighbour," HAVE, in which the segment -AVE has a different pronunciation) are named with longer latencies than regular words like WADE (for which there are no orthographic neighbours containing segments with conflicting pronunciations). In fact, naming latency for regular words with inconsistent neighbours (words like WAVE) was as slow as for frankly irregular words like HAVE. A GPC-based account cannot explain why WAVE should be dealt with differently from WADE. Glushko's second important finding concerned naming latencies for nonwords; he found that nonwords with inconsistent word neighbours (e.g., BINT – cf. MINT, PINT) produced longer naming latencies than those with only consistent neighbours (e.g., BINK). This result is especially damaging to GPC theory since on that theory all nonwords are dealt with in the same way (by GPCs) and no reference at all is made to the pronunciations of any real words when nonwords are being read aloud.

If the reading aloud of nonwords is not accomplished by the application of GPCs, then how is it done? Glushko (1979, p. 686) proposed: "A letter string is not read aloud by retrieving a single pronunciation from memory or by employing abstract spelling-to-sound rules. Instead, it appears that words and pseudowords are pronounced using similar kinds of knowledge: the pronunciations of words that resemble them and specific spelling-to-sound rules for multiletter spelling patterns."

There are a number of difficulties with this proposal. Firstly, English contains a good number of words – *sew, yacht,* and *colonel* are examples – which contain multiletter sequences whose spelling-to-sound relationships are unique. The pronunciation of *ew* as /soω/ is unique to *sew* and its derived forms; therefore, knowledge of the pronunciations of words which resemble *sew* orthographically simply could not be used as part of a process which determines how *sew* is to be pronounced. Surely the only way in which such a word could be read aloud correctly is in fact by retrieving a single pronunciation from memory. Secondly, it is not difficult to produce pronounceable *nonwords* which have no words resembling them; indeed, Table III of Coltheart, Besner, Jonasson, and Davelaar (1979) contains a list of such nonwords. These nonwords were all of the structure CVVC, and they were selected so that no English word began or ended with the initial CVV- component of any nonword, and no English word began or ended with the terminal -VVC component of any word. An example is *joov.* When subjects were asked to read this aloud, the response /dʒuv/ was produced by 93.1% of these subjects; but since no English word begins or ends with *joo,* and no English word begins or ends with *oov,* how could the reading aloud of this nonword make use of the pronunciations of words which resemble it, or make use of multiletter spelling patterns where "multiletter" means "more than one grapheme"? Surely the only way in which such nonwords could be read aloud is by employing abstract spelling-to-sound rules at the level of single graphemes and phonemes?

Thus words like *sew,* on the one hand, and nonwords like *joov,* on the other, represent examples which conflict with Glushko's claim that a letter string "is not read aloud by retrieving a single pronunciation from memory or by employing abstract spelling-to-sound rules." The former method of reading aloud is required for words like *sew,* and the latter method is required for nonwords like *joov.*

A further difficulty arises in connection with Glushko's view that words and nonwords are read aloud by the same procedure. In the syndrome known as phonological dyslexia (discussed below), the reading aloud of nonwords is severely impaired, whilst the reading aloud of words (at least in the case of single-morpheme content words) is virtually intact. How could such a dissociation arise if the same mechanism is used for reading aloud both words and nonwords? One could reply to this objection by arguing that nonwords are intrinsically more difficult to read aloud than words (although it is by no means clear whether such a claim could itself be consistent with Glushko's view), and that when the reading system is stressed by brain damage, it is the more difficult tasks which are the most impaired. The problem with this objection is that in another form of acquired dyslexia, namely surface dyslexia (also discussed below) it appears possible to argue that the reading aloud of at least certain kinds of words (irregular words) is more impaired than the reading aloud of nonwords: certainly, surface dyslexics are better at judging whether two printed nonwords are homophones (e.g., *afe/aif* versus *afe/auf*) than at judging whether printed irregular words are homophones (*hear/here* versus *wear/were*). Consequently there are circumstances in which deriving phonology from print may be worse for words than for nonwords (surface dyslexia) and also circumstances where it is worse for nonwords than words (phonological dyslexia); this "double dissociation" between words and nonwords is difficult to reconcile with the view that reading aloud of the two types of stimuli uses a single mechanism.

A final problem relevant here is that it is unclear what the nature of the single mechanism postulated by Glushko for reading words and nonwords actually is; it appears that two rather different views are advanced at different points in Glushko's paper.

On one view, subjects map multiletter sequences onto multiphoneme sequences, so that the essential knowledge used for reading aloud is a system of multiletter spelling-to-sound correspondences. This is what appears to be argued when it is proposed that nonwords "might be parsed into smaller units to activate analogies or specific spelling-to-sound correspondences"

(p. 678) and that "words are generally pronounced using larger units (up to the entire letter string)" (p. 675).

An alternative view proposed by Glushko is that letter sequences are *not* divided up into smaller (subword) units: instead, a letter sequence activates the internal representations of all "orthographic neighbours," and this family of activated words is then subjected to some kind of segmentation and synthesis operation. For example, a nonword like FENT might activate a family of words ending in -ENT and a family of words beginning F-; by appropriate segmentation and synthesis operations upon these sets of words the pronunciation /fent/ is computed. This alternative view is advanced (p.683), at the expense of the multiletter correspondence view: "Readers might pronounce the novel word BINT using a generalization about -INT. Perhaps such independent representations of orthographic structure do not exist at all: the -INT rule might exist only implicitly in the integrated activation of words like HINT, MINT, and TINT."

These two accounts of the procedure used for reading aloud are clearly rather different: for example, the second one uses knowledge about the pronunciations of specific words to read nonwords aloud, whilst the first does not. It is not at all clear whether either procedure is consistent with the data on reading nonwords and words aloud. If words can be read aloud using the whole word as a unit, why do words with subunits having inconsistent pronunciations (e.g., *wave*) take longer to initiate in reading aloud than words without such inconsistency (e.g., *wade*)? On the other hand, if a word activates a family of orthographic neighbours, it is unclear how the ultimate pronunciation is chosen: for example, if *tomb* activates *comb, tomb, bomb, womb,* and *aplomb,* how does the reader choose to pronounce *o* as /u/ and not /α/ or /oω/?

If each procedure fails in certain circumstances, perhaps this is why Glushko (1979, p. 686) at one point proposes that both procedures are used: but this makes matters even more complicated, since there is nothing said about what determines when one procedure is responsible for reading aloud and when the other is.

I conclude from this analysis of Glushko's work not only that his results are inconsistent with a theory of reading aloud in which nonwords are read aloud solely via GPC's, but also that the alternative theoretical framework for reading aloud which he proposes is no more satisfactory.

We are left, therefore, without a viable theory concerning how people read words and nonwords aloud.

An attempt has been made to deal with some of these problems by Marcel (1980). His view is that the mapping of letters to sounds in reading aloud occurs at the grapheme-phoneme level and at various higher levels simultaneously, up to the highest possible level at which letter sequences are recognized. For words, this highest level is the whole letter string; for nonwords, since they are unfamiliar letter sequences, the highest level of recognizable letter sequence is smaller than the whole letter string. The ultimate decision as to pronunciation relies upon an overriding mechanism according to which the highest level (largest letter-sequence unit) achieved is the one subsequently used. However, lower levels do affect the time taken to decide upon pronunciation: this must be so, or else the inconsistent phonological representations generated by the final three letter sequence in the word *have* would not affect naming latency for this word. This theoretical approach has not yet been worked out at a level of detail which would allow a satisfactory assessment of its success in accounting for reading aloud: for example, nothing is said about how letter-sound relationships below the level of the entire letter string affect the derivation of a phonological representation of the letter string as a whole. This is true for both *words* (where the problem is why the reader does not rely simply on the mapping using the whole word) and *nonwords* (where the problem is how the reader decides upon a pronunciation for, e.g., *tave,* given the pronunciations of all the words orthographically similar to this nonword, including *have* and *wave*).

A recapitulation may be in order here. This discussion of the work of Glushko (1979) was prompted by considering whether one needs to postulate two separate mechanisms for reading aloud. If one assumes that nonwords are read aloud using GPCs, then one does need to postulate two such mechanisms; but Glushko's results are inconsistent with the assumption that nonwords are read via GPCs. Glushko argues instead that there is one mechanism which accompanies reading aloud both for words and nonwords; here it is claimed that the mechanism he proposes is an unworkable one, and furthermore that there is some neuropsychological evidence for the view that two different mechanisms for reading aloud do exist.

Precisely what these mechanisms are is unknown, if one must abandon the concept of nonlexical phonological recoding using GPCs. I will refer to the two mechanisms as "word pronunciation" and "nonlexical phonological recoding" and, without being able to offer ideas as to how each actually works, will simply define them as follows. The *nonlexical mechanism* is so termed because it can be used to read aloud letter strings which have not previously been seen and hence which do not have lexical entries (i.e., nonwords); the term "nonlexical" should not be taken to mean that this mechanism makes no use of lexical information when determining the pronunciations of such stimuli. Word pronunciation is a *lexical* mechanism in the sense that it can only be used for letter strings which have been seen before and about which the reader has previously stored information concerning pronunciation (pronunciation of the string as a whole, that is).

If a reader had never seen the words *new* and *sew* before, and so had to use the nonlexical mechanism to read them aloud, he could not pronounce both correctly. Studies of nonword reading indicate that the pronunciation given to the grapheme *-ew* here would probably be /u/ because this is how terminal *ew* is pronounced in most English words, and information about the usual pronunciation of a grapheme is what determines how it is pronounced when it is part of a grapheme sequence whose pronunciation as a whole has not previously been learned by the reader. It follows from this that one may deduce that the nonlexical mechanism is being used to read words aloud if one observes that errors in reading aloud are more common with irregular words like *sew* than with regular words like *new.* Furthermore, not only should *sew* be read wrongly: it should be read as /su/ if it is being read by the nonlexical mechanism. This kind of error may be termed a "regularisation"; and, as I have already mentioned, such errors are characteristic of one form of acquired dyslexia, surface dyslexia.

If a reader is using the *non*lexical mechanism to read *words* aloud, then there must be an impairment of the lexical mechanism, since it would normally be used for reading words. The opposite impairment – an impairment of the nonlexical mechanism – would be revealed by poor reading aloud of nonwords with good reading aloud of words; and, as has also already been mentioned, this pattern is characteristic of phonological dyslexia.

It is the model described in Figure 1, then, which I will use to interpret the patterns of deficits and preservations of reading abilities displayed in the various forms of acquired dyslexia which I am about to describe. The general approach here is to propose, for each acquired dyslexia, that some of the components of the model are impaired, whilst the remainder are intact. Different acquired dyslexias will correspond to impairments of different components or sets of components. One then needs to show that impairment of a particular component or set of components would cause the system as a whole to read in the way that sufferers from the relevant form of acquired dyslexia do.

A successful demonstration that a particular selective impairment of the model would produce reading symptoms which parallel those of a particular acquired dyslexia achieves two things. The first is that an economical description of the disorder, in information-processing terms, has been obtained: a constellation of symptoms has been reduced to one or a few basic impairments. The second is that one's confidence in the usefulness of the model must be increased each time it deals in a plausible way with an acquired dyslexia.

Furthermore, one can test one's hypotheses as to which components are intact and which are impaired because tests can be devised which are specific to each component: these have already been mentioned. A patient who succeeds at cross-case matching with nonword stimuli has an intact ALI component. Success at lexical decision indicates an intact word recognition component. Success at judging whether or not words are synonyms, at obeying printed commands, or at matching words to pictures indicates an intact word comprehension component. Because irregular words can be read aloud only by using the word pronunciation component, intactness of this component is indicated by competent reading aloud of irregular words; and because nonwords can be read aloud only by using nonlexical phonological recoding, this component must be intact if nonwords can be read aloud.

Five varieties of acquired dyslexia will now be described, and attempts will be made to interpret each one within the theoretical framework offered by Figure 1. In this kind of enterprise, it is important that the descriptions of the acquired dyslexias be as atheoretical as possible: one needs to preserve a proper distance between, on the one hand, the data characterising the syndrome, and, on the other hand, the theoretical framework being offered to explain these data. Only in this way can the data survive when the theory expires. Consequently, it is hoped that even if evidence emerges (from studies of normal readers, for example) which compels one to reject or radically to modify the model described earlier in this section of the paper, the characterisations of acquired dyslexias presented in the following section of the paper will retain their validity, and will therefore be of use in future attempts at building models of reading.

VARIETIES OF ACQUIRED DYSLEXIA

Damage to the brain can impair reading in a number of different ways. Some patients, for example, show no impairments in dealing with single words, whilst showing reduced ability to comprehend continuous text; at the other extreme, patients may be entirely unable to comprehend or read aloud single words. It is difficult to study the former kind of patient, because so little is known about the comprehension of continuous text and how it may be measured, and it is difficult to study the latter kind of patient because of limitations on the amount of data which can be collected from someone with so severe an impairment. For these reasons progress in studying acquired dyslexias has been achieved mainly with patients who have both impairments and preservations at the single word level: patients who can perform some tasks with single words but not others. All of the varieties of acquired dyslexia described here are of this type.

Letter-by-letter reading

A symptom observed only in this form of acquired dyslexia is that the patient often or always can only read a word aloud if he first *names* each of the letters in the word: thus city – "/si/ . . . /aɪ/ . . . /ti/ . . . /waɪ/ . . . /sɪti/." These patients use letter *names,* not letter *sounds,* when they read letter-by-letter.

This disorder is referred to as "word-form dyslexia" by Warrington and Shallice (1980); also, since writing is usually intact in letter-by-letter readers, it seems highly likely that the traditional terms "pure alexia" and "alexia without agraphia" are synonymous with "letter-by-letter reading."

Some letter-by-letter readers have intact letter naming (e.g., case R. A. V. of Warrington and Shallice, 1980) and so their reading aloud, though extremely slow, is accurate. Other letter-by-letter readers make errors in letter naming (e.g., case C. H. of Patterson and Kay, 1980) and so their reading is not only slow but also inaccurate.

It is common in these patients that Arabic numerals are read aloud with greater ease than letters. This "number sparing" could, of course, be an effect of meaningfulness, but this appears not to be so: case B. W. (Coltheart, Bailey, and Masterson, unpublished observations) responded more promptly and more easily to four-digit numbers which he was asked to read as dates (e.g., 1911 → "nineteen eleven") than to single numbers written alphabetically (*nine* → "nine"); and he was faster at sorting single numbers into "odd" and "even" piles when they were written as Arabic digits than when they were written alphabetically.

In this syndrome nonwords can be read aloud, but (like words) they must be read letter-by-letter before the whole nonword can be uttered.

One possible theoretical interpretation of this syndrome in terms of Figure 1 is that it arises because of a disturbance in the transmission of information from the ALI system to the word recognition component; but if this were the only difficulty, the patients would not read *nonwords* letter-by-letter. The difficulty would thus appear to arise at all outputs from the ALI system: in particular, there is impaired or abolished output from this system both to the word recognition system and also to the nonlexical phonological recoding system.

Some subjects have intact output from the ALI system to the letter-name system; others, those who make errors even in naming single letters, may have a defect in the letter identification process itself, in addition to impaired or abolished communication between the ALI system and the word recognition and nonlexical phonological recoding components.

For these patients, then, there is a barrier at a very early stage of the reading system, preventing information from print reaching higher stages of the system in the normal way. The only way to circumvent this barrier is to name the letters in a printed stimulus. The ability to comprehend and to utter a word after hearing it spelled aloud is a normal linguistic ability, and this ability is intact in the letter-by-letter reader, since it does not require there to be any communication between the ALI sytem and the word recognition or nonlexical phonological recoding systems: thus an impairment of this kind of communication would not prevent a reader from being able to identify a word from hearing it being spelled, and hence spelling of individual letters is a strategem which the letter-by-letter reader can use to gain access to semantics or phonology from print.

Number sparing is of interest here. The fact that a patient may read 9 promptly, whilst only being able to read *nine* by first spelling the letters, could be explained by supposing that the route from ALIs to letter names includes links from number identities to number names. However this does not seem to be the explanation of number sparing, because patient B. W. could read arbitrary two-digit numbers (17 → "seventeen") rapidly and accurately whereas he was slow and inaccurate at reading single letters when prevented from tracing them with his finger (37/52 correct). This suggests that the system described in Figure 1 is specifically for the processing of *letters* – that is, this system is required when alphabetically-written material is to be processed, whereas there is some other system which can be used for processing ideographically-printed material. Besner and Coltheart (1979) provide evidence from normal readers of English that different mechanisms are involved in the reading of alphabetic and ideographic material.

A further interesting aspect of the behaviour of patient B. W. is that he did not make errors in letter naming if allowed to trace the letters with his finger. The accuracy of his tracing indicates that his difficulty in naming letters was not a low-level perceptual difficulty: if there had been such a defect, visual representations of letters would not have been of sufficient quality to allow correct tracing (B. W. did not trace over letters, but made tracing movements some distance away from them).

Phonlogical dyslexia

The essence of this syndrome is a severe impairment of the ability to read *nonwords* aloud, coupled with preservation of the ability to read *words* aloud – at least when these words are single-morpheme content words. The syndrome was first described by Beauvois and Dérouesné (1979) and Dérouesné and Beauvois (1979) who discuss four cases, one (R. G.) in considerable detail; there are three other published cases (Shallice and Warrington, 1980, cases G. R. N. and B. T. T.; Patterson, in press, case A. M.). Some of the information given here about these patients was provided by personal communications from these authors.

Because of the small number of cases, this syndrome is not yet clearly defined, and we cannot yet evaluate the significance of some differences between the patients. For example, R. G.'s writing was only mildly impaired, and his spelling errors were almost always phonologically correct, such as writing "enfant" as *enfans* or "eglise" as *aiglise;* A. M., on the other hand, had a severe writing deficit and never produced phonologically correct misspellings. However, all of these patients showed a major deficit in nonword reading coupled with good performance in reading single-morpheme content words. For example, R. G. read 40/40 nouns aloud correctly, whilst being able to read aloud only four of 40 four-letter or five-letter nonwords; G. R. N. performed at a normal level on reading tests involving reading aloud of single words, and read 39/40 words correctly, whilst being able to read only 3/40 nonwords. On another occasion, her scores were 19/20 with words and 1/20 with nonwords.

This dissociation between word reading and nonword reading is also characteristic of deep dyslexia (described below); but the two syndromes nevertheless must be distinguished. Deep dyslexics make semantic errors in reading aloud, and their reading aloud is better with concrete than with abstract words; neither of these symptoms occurs in phonological dyslexia. Furthermore, the incorrect responses made by phonological dyslexics are sometimes nonwords, whereas deep dyslexic responses, to words or nonwords, are essentially always words.

In addition to the disparity between word reading and nonword reading, there are several other symptoms evident in phonological dyslexia. Amongst these are:

1. Visual errors in reading aloud nonwords (e.g., *bef* → "beef" or *clest* → "calest").

2. Derivational errors in reading aloud words containing bound morphemes – that is, such words may be read with their root morphemes correct but their bound morphemes incorrect.

3. Function-word substitutions – when a function word is misread, the response is likely to be another function word, even a visually and semantically dissimilar one (*yet* → "that", *those* → "you").

4. For several of the patients function words are more likely to be misread than content words. However, this has not been observed with cases G. R. N. and B. T. T., the two patients studied by Shallice and Warrington (1980). Since the other phonological dyslexics studied were not very impaired at reading function words, it is necessary to test such patients with a large number of function words if one is to show a deficit, and this has not been done with G. R. N. and B. T. T.; so it is not yet entirely clear whether or not a deficit with function words is an invariable aspect of phonological dyslexia.

5. In two patients (R. G. and A. M.) an attempt has been made to discover whether nonword reading is improved when the nonword is a pseudohomophone (i.e., sounds identical to a real word); in both cases such improvements were observed.

6. Lexical decision ability has been studied in one patient (A. M.); it was intact.

7. Patient A. M. could match uppercase letters to their lowercase equivalents perfectly; but his naming of single letters was very much impaired.

The interpretation of this dyslexia is relatively straightforward: the syndrome arises when brain damage impairs the operation of the nonlexical phonological recoding component of the reading system. This is sufficient to explain the main feature of the disorder, namely, the severe difficulty in reading aloud nonwords. Some other aspects of the syndrome might also be explained in this way. Visual errors where the response is a word and the stimulus is a nonword (e.g., *bef* → "beef") could occur because of attempts to use the word pronunciation component to read nonwords aloud. In deep dyslexic patients, who, like phonological dyslexics, have great difficulty in reading nonwords, it has been noted that, when they attempt this task, they produce visually similar words as responses. The method, presumably, is to locate an entry in the word recognition component which is orthographically highly similar to the nonword stimulus – "approximate visual access" (Patterson, 1978; Coltheart, 1980 c).

The finding that success in reading nonwords aloud is increased when the nonwords are pseudohomophones (i.e., sound identical to real words) might perhaps be explained in the following way. If a normal reader is asked to read *phocks* and to decide whether it sounds identical to the name of an animal, he can do so. Therefore it is possible to use the result of nonlexical phonological recoding to access the word comprehension component of the system described in Figure 1. Such access could not occur with a nonword like *phacks;* it could only occur with pseudohomophones. If in phonological dyslexia difficulties in using nonlexical phonological recoding arise not only in converting print to phonology, but also in converting phonology to articulation without being able to use a stored set of prelearned phonological representations, then pseudohomophonic nonwords will encounter only the first of these difficulties, whilst non-pseudohomophonic nonwords will encounter both. This may be why reading aloud is better for the former than for the latter.

Although the symptoms just discussed might all reflect an impairment of nonlexical phonological recoding, it is not obvious why such impairment should affect the reading of *words* in any way. Nevertheless, phonological dyslexics display two kinds of difficulty in reading words: they make derivational errors, and they may be unable to read some function words aloud correctly. These symptoms are interesting because they could be taken to indicate a role for nonlexical phonological recoding in normal reading of single words, a role which has been disputed (Coltheart, 1980b). If the *only* impairment of the reading system in phonological dyslexia is in the component responsible for nonlexical phonological recoding, then the difficulties with derived words and function words evident in this syndrome would imply that the normal reader uses nonlexical phonological recoding in reading such words.

Suggestions compatible with these ideas have been made. For example, in expositions of the logogen model, it is often proposed that the entries in the visual input logogen system (the word recognition component in Figure 1) correspond not to words but to morphemes, and root morphemes at that; in this case "the input logogen which transduces between stimulus information and the cognitive system would be exactly the same unit for *walk, walked,* and *walking.* For normal comprehension, information about affixes must reach the cognitive system by a separate (though largely unspecified) process" (Patterson, 1980, p. 289). This view has been proposed by Morton (1978): in considering whether or not morphemically related words such as "sing," "sings," "singing," "singer," and "singers" would each possess independent representations in the word recognition (i.e., visual input logogen) system, he observed that "this seems very inefficient, as one could make do with one logogen plus other devices for recognizing the suffixes and adding them on in production."

Patterson (in press) discusses the possibility that her "largely unspecified process" (which corresponds to Morton's "other devices") might depend upon nonlexical phonological recoding. If this were so, of course, an impairment of nonlexical phonological recoding would result in the occurrence of derivational errors: reading responses in which the root morpheme is preserved whilst bound morphemes are processed incorrectly.

The theoretical approach proposed here by Morton and by Patterson is based upon the idea that a word consisting of a root morpheme plus one or more bound morphemes is segmented into its morphemic constituents prior to access to the visual input logogen system: this is necessary because only the root morpheme is represented in the input logogen system. For the approach to work, then, it would have to be possible to analyze words into their morphemic constituents prior to recognizing them. What kind of procedure could accomplish this? For some words it seems simple enough; for a word like UNSELECTIVELY one can imagine the common bound morphemes UN-, -IVE, and -LY being recognized and deleted, leaving the free morpheme SELECT in isolation. However, there are many words of English whose morphemic structure is much less regular. Consider the past tenses of the verbs GO and DEPART: one could recover DEPART from DEPARTED by deleting the familiar bound morpheme -ED, but how could one recover GO from WENT?

Perhaps it could be argued that irregular inflections like WENT have their own independent visual input logogens, whilst regular inflections like DEPARTED do not, and must be recognized via the visual input logogen for the root morpheme. There are two difficulties for such a proposal. The first is that the main evidence for Morton's claim that DEPARTED is recognized via DEPART is that DEPARTED primes DEPART in a way that is characteristic of a word priming itself (Murrell and Morton, 1974); and hence, if WENT and GO have their own input logogens, WENT should not prime GO. Stanners, Neiser, Hernon, and Hall (1979), however, did find that irregular past tenses primed their root morphemes (although the effect was smaller than the priming of root morphemes by *regular* past tenses). The second problem concerns derivational errors in deep dyslexia. Since nonlexical phonological recoding is abolished or greatly impaired in deep dyslexia (see below) just as it is in phonological dyslexia, the view that derivational errors in phonological dyslexia occur because of this impairment presumably implies the same explanation for derivational errors in deep dyslexia. Now, if DEPARTED is processed by accessing DEPART and using nonlexical phonological recoding to process the bound morpheme -ED whereas WENT is processed directly via its own logogen, one would expect derivational errors of the form *departed* → "depart," but not of the form *went* → "go." However, inspection of examples of derivational errors provided in Coltheart, Patterson, and Marshall (1980: see Table 2.6, pp. 32-34, and also Appendix 2) reveals numerous instances where the stimulus consists of a free morpheme plus a bound morpheme, where these two morphemes are combined in an irregular way, and where the incorrect response preserves the free morpheme, with the bound morpheme having been lost. Some examples are *truth* → "true," *hatred* → "hate," *heat* → "hot," *stolen* → "steal," *mercantile* → "merchant," *met* → "meet," *paid* → "pay," *built* → "building," *speech* → "speak," and *English* → "England."

Even the idea that morphemically regular words could be segmented into their constituents encounters difficulty: if there is a procedure which identifies RINGED as the past tense of the verb RING by deleting the -ED and determining that what remains is the root morpheme of a verb, how could this procedure avoid identifying SINGED as the past tense of the verb SING?

The concept of prelexical morphemic segmentation inherent in the views of Morton and of Patterson thus encounters a number of difficulties, which require resolution if this concept is to be retained. However, if one rejects the concept, then no explanation of the relationship between the occurrence of derivational errors and the impairment of nonlexical phonological recoding in phonological dyslexia is available, and hence two alternatives, both unsatisfactory, remain. One is that the two symptoms are causally related, but in an unknown way; the other is that the two symptoms are independent, and here one cannot explain why all patients with an impairment of nonlexical phonological recoding (whether deep dyslexic or phonological dyslexic) make derivational errors.

An unnamed dyslexia

I refer to a case described by Schwartz, Marin, and Saffran (1979) and Schwartz, Saffran, and Marin (1980). Although this dyslexia has not yet been accorded a name, and although the data come from only one patient, the disorder is of sufficient theoretical importance to deserve discussion. The patient was a 62-year-old woman with a progressive presenile dementia. She could not demonstrate comprehension of printed nouns by matching them to pictures, and her sorting of printed nouns into broad semantic categories was poor. Nevertheless, she could read aloud both words and nonwords well; and what is crucial here is that she could read aloud irregular words correctly. For example, she correctly read aloud such irregular words as *blow, one, post* and *climb* whilst also, on the same occasion, correctly reading aloud the regular words *cow, bone, cost* and *limb.*

If someone reads the segment -ow as /oω/ in *blow* but as /aω/ in *cow,* then he or she must be able to access information about the phonology of specific words, rather than, for example, using general rules for mapping graphemes onto phonemes, since such general rules could not be used to generate different terminal phonemes for *blow* and *cow*. At the same time, this patient could also read aloud even when specific information about phonology could *not* be available, since she could read nonwords aloud. Since printed words could not be comprehended by this patient whilst irregular words could nevertheless be read aloud, this means that access to the stored phonological representation of a word can be achieved even when access to its stored semantic representation cannot. In terms of Figure 1, this means that one must be able to gain access to the word pronunciation component of Figure 1 directly from the word recognition component without needing to pass through the word comprehension component. The question of direct connections from the visual input logogen system (word recognition component) to the output logogen system (word pronunciation component) was raised by Morton and Patterson (1980, p. 94): "Now that input and output logogens (once a single system) have been separated, the question of a direct connection between them must be considered. It is an open question .... For present purposes, the existence of this input-output connection in the normal system will be assumed". It is difficult to see how one could design experiments with normal subjects which could provide evidence concerning whether one need postulate such direct connections or not; the unnamed acquired dyslexia being discussed here, on the other hand, is very difficult to interpret unless one does postulate such connections.

Surface dyslexia

This disorder was named and first described by Marshall and Newcombe (1973); it has also been discussed by Holmes (1973, 1978) and Marcel (1980) and another case is described by Shallice and Warrington (1980, case R. O. G.), who refer to surface dyslexia as "semantic dyslexia."

In this disorder, and not in any of the other disorders, the patient has more difficulty in reading irregularly-spelled words than matched regularly spelled words: for example, R. O. G. correctly read 36 of 39 regular words but only 25 of 39 matched irregular words. (These two matched sets of words are listed in Coltheart et al., 1979). Furthermore, in surface dyslexia misreadings of irregular words often take the form of "regularisations"; i.e., of treating an irregular word as if it were regular: for example *pint* → /pɪnt/ and *broad* → /broʊd/.

An important aspect of this syndrome is that it exists not only as an acquired dyslexia but also as a developmental dyslexia. This was first claimed by Holmes (1973), who described four developmental cases in addition to two acquired cases; and it has been confirmed by comparisons we (Coltheart, Masterson, Prior, Byng, and Critchlow, submitted) made between an acquired surface dyslexic (A. B.) and a developmental surface dyslexic (C. D.). Whether other varieties of acquired dyslexia also exist in developmental forms is an important question which will not be answered until individual case-study work on developmental dyslexia is more prevalent (though see, for example, Boder, 1973). It is already clear, however, that exactly the same pattern of reading errors, the pattern characteristic of surface dyslexia, occurs in some children who have failed to acquire competence in reading despite apparent neurological normality as well as in some adults who had learned to read competently but then suffered a brain injury which left their reading impaired.

If surface dyslexia consisted solely of difficulty in reading irregular words aloud with frequent "regularisations" of these irregular words, one could interpret it by proposing that some words are treated as if they were nonwords during reading aloud: such nonword treatment would allow regular words to be read aloud correctly whilst producing incorrect reading (in fact, regularisation) of irregular words. However, errors of this sort are not the only kinds of error which occur in the oral reading of surface dyslexics.

problem arises here which does not seem to arise in connection with the other varieties of acquired dyslexia. In the other varieties it its possible to describe the various symptoms in an entirely atheoretical way. In the case of surface dyslexia, however, it is curiously difficult to describe some of the symptoms atheoretically. For example, errors like *incense* → "increase" were described by Marshall and Newcombe (1973) as "partial failures of grapheme-phoneme conversion," since the grapheme *c* should be assigned the phoneme /s/, not the phoneme /k/, when the following grapheme is *e*. Here Marshall and Newcombe were assuming that whenever nonwords are read aloud (and, hence, when words are treated as nonwords), the procedure used to do this is grapheme-to-phoneme conversion. However, this assumption has subsequently been challenged (Glushko, 1978; Marcel, 1980), which compromises not only Marshall and Newcombe's theoretical interpretation of the syndrome but also, more seriously, their empirical description of it. This example illustrates the point made earlier, that it is vital to characterise each acquired dyslexia in atheoretical terms.

Advances in the understanding of surface dyslexia have recently been made by testing reading comprehension as well as reading aloud: this work, carried out with the developmental surface dyslexic C. D. and the acquired surface dyslexic A. B. by Coltheart, Masterson, Prior, Byng, and Critchlow (submitted) has revealed the following additional features of surface dyslexia:

1. Not all misreadings of words can be explained as the consequence of treating an irregular word as a regular word. There are letter deletions (*frog* → "fog"), letter additions (*an* → "and"), letter substitutions (*life* → "lift"), and letter-order errors (*sign* → "sing").

2. When a word is misread as another word, the surface dyslexic always comprehends the printed word as the word spoken, even if the comprehension is tested before the word is read aloud. When a word is misread as a nonword, the comprehension response will be "don't know". For example, C. D., when asked to define and then read aloud the word *gauge*, said "a big dip . . . gorge"; and A. B., with the same task, produced *scarce* → "fairly serious cut . . . a mark to remain after . . . scar."

3. Misreadings are not due to errors at the letter identification level. When C. D. and A. B. were given single printed words and asked to define them, then to read them aloud, then to read their letters from left to right, observations of the following kind were made:

enigma → "a picture . . . image . . . E,N,I,G,M,A" (C. D.)
check → "a part of your face . . . cheek . . . C,H,E,C,K" (C. D.)
thyme → "music that the orchestra's playing, sort of meaning of what they're playing . . . theme . . . T,H,Y,M,E"
subtle → "to stand firm . . . stable . . . S,U,B,T,L,E" (A. B.)

Thus, when the reading aloud response is wrong, comprehension is governed by what is *said,* whilst spelling is governed by what is *seen.* In these tests, where errors of oral reading and of comprehension were fairly frequent, errors in spelling aloud were virtually non-existent.

4. Interesting results are obtained with homophones: even when these are read aloud correctly, they may be misunderstood. For example, again when the task is to define a printed word first, then read it aloud, then spell it, one observes:

bury → "a fruit on a tree . . . /bεri/ . . . B,U,R,Y" (C. D.)
bowled → "fierce, big . . . /boωld/ . . . B,O,W,L,E,D" (C. D.)
mown → "to be grumpy . . . /moωn/ . . . M,O,W,N" (A. B.)
route → "what holds the apple tree in the ground and makes it grow . . . /rut/ . . . R,O,U,T,E" (A. B.)

The basic types of error made in surface dyslexia may be illustrated by considering the following hypothetical example: suppose a surface dyslexic were given the printed word *none* to define, to read aloud, and to spell.

1. One pattern which might occur is: *none* → "Acquainted with . . . known . . . N,O,N,E". Here there has been a "regularisation"; for most words ending *o* plus consonant plus *e*, the *o* is pronounced /oω/.

2. Alternatively, one might find the following: *none* → "A religious woman .../nʌn/...N,O,N,E". Here the word is understood as its homophone pair.

3. Finally, the word might be read as "one," "nonce," "bone," or "neon"—that is, a letter deletion, addition, substitution or order error might occur.

Whatever the surface dyslexic does, however, two things will virtually always be true: spelling aloud will be correct no matter how incorrect the reading response is, and the word will be comprehended in terms of the spoken response, not the printed stimulus.

Little is known about the speech comprehension of any surface dyslexics except A. B. and C. D. In these two cases, comprehension of single *spoken* words (tested by requiring definitions) appeared to be intact. Thus failures to comprehend single printed words cannot be ascribed to defective semantic representations in the word comprehension component (assuming that the same semantic representations are accessed from print as from speech). We must also assume that the ALI system is intact, because when printed words are spelled aloud errors are not made.

Consider now the three types of error described in the hypothetical example given above. When *none* is read as "known" and understood as "known" there must have been a failure of communication somewhere along the route from the ALI system (itself intact) to the word comprehension component (itself intact). If this failure were at a point *after* correct access to the entry for *none* in the word recognition system, then a double deficit would need to be postulated: from word recognition to word pronunciation (if this route were intact, the word would be pronounced correctly) and from word recognition to word comprehension (if this route were intact the word would be comprehended correctly). Thus, for reasons of parsimony if no other reasons, one might prefer to suppose that the correct entry for *none* in the word recognition system was not accessed. The reader in this case, whether he is trying to read aloud or to comprehend this printed word, must fall back upon the nonlexical phonological recoding route, and because *none* is an irregular word, it will be encoded wrongly, as /noʊn/. The resulting incorrect phonological representation is the only encoding of the word available to the reader, and if this phonological encoding is used to access semantics (by a route perhaps the same as that used for speech comprehension), then the word will be both misunderstood and mispronounced. Thus failures of access within the word recognition component will, with irregular words, produce regularisation errors in both reading aloud and silent comprehension.

When *none* is read correctly but nevertheless still misunderstood (as nun), something else must have occurred. Because *none* is irregular, a correct oral reading requires access to the correct entry in the word pronunciation component; and such access can only occur if there has been prior access to the correct entry in the word recognition component. Therefore the failure to comprehend *none* correctly when it is read aloud correctly cannot be explained as a failure of access at the word recognition level: it must instead be due to a failure of communication between the word recognition and word comprehension components. When such a failure of communication occurs, the reader uses a phonological representation (retrieved from the word pronunciation component) to access the word comprehension component (i.e., uses the access method by which speech is comprehended). When a word is a homophone, this method of comprehending print does not allow the reader any way of deciding which member of a set of homophones the word is; thus a word is liable to be comprehended as one of its homophones.

In sum then, these two types of error in surface dyslexia occur because failures of access to or exit from the word recognition component compel the use of "phonological reading." There are two types of phonological reading, corresponding to the two routes from print to phonology: use of the lexical route produces correct pronunciation but possible confusion between homophones, whilst use of the nonlexical route produces with irregular words a "regularisation" and hence an error in both comprehension and pronunciation. What these two types of malfunctioning in surface dyslexia have in common is that phonological aspects of the reading system are working perfectly (retrieval from word pronunciation is intact and the non-lexical phonological recoding mechanism functions normally).

As already noted, however, there is a third category of error seen in surface dyslexia: the letter deletion, alternation, addition, or position error. One possible explanation of these is that, when the surface dyslexic cannot find an entry in the word recognition component corresponding to the word he is looking at, he does not always use the nonlexical phonological recoding system: he may sometimes settle for an entry in the word recognition system belonging to a word orthographically very similar to, but not identical with, the word he is looking at. This kind of "approximate visual access" strategy is discussed elsewhere in this paper, in connection with phonological dyslexia, and considered in more detail by Patterson (1978) and Coltheart (1980c) in relation to deep dyslexia. However, this explanation is probably wrong, because it implies that letter deletions, changes, additions, and position errors should only occur when the response made is a word, and this is not so, as the following examples from C. D. show: *girter* → /gɩte/, *drɩg* → /drɩd/, *drace* → /dræns/, *civid* → /saɩdɩv /, *golt* → /glot/, *pleck* → /plæk/.

A further complication here stems from considering the original interpretation of surface dyslexia offered by Marshall and Newcombe (1973). They suggested that there are two defects of the reading system in surface dyslexia. Translating from their terms into the vocabulary of Figure 1, the two defects referred to are (a) communication from the word recognition component to the word comprehension component sometimes fails; (b) the mechanism which performs nonlexical phonological recoding has become prone to error. Evidence indicating the need to postulate the first of these defects has been given above; but it has been assumed so far in this paper that nonlexical phonological recoding is intact in surface dyslexia. As evidence for an impairment of the use of grapheme-phoneme conversion rules, Marshall and Newcombe (1973) offered examples like *describe* → "describ" and *lace* → "lass" (here the rule according to which final *-e* should lengthen the preceding vowel is not being applied) or *gauge* → "jug" and *recent* → "rikunt" (here the rules concerning hard and soft *g* and *c* are not correctly applied). However, one could instead interpret such errors as letter deletions or letter changes; and there are many letter deletions and letter changes which could not be interpreted instead as errors of the operation of nonlexical phonological recoding (see examples of these errors given earlier). It is thus not clear whether one does need to postulate a defect of nonlexical phonological recoding in surface dyslexia; it may be that all errors which might be attributed to such a defect could instead be explained as letter deletions, changes, additions, or position errors, and it certainly is the case that one cannot explain all errors of the latter kinds as arising through defective operation of the nonlexical phonological recoding mechanism.

In this analysis of surface dyslexia, I have argued that two of the types of reading error can be explained in terms of a failure of "visual reading" which force the surface dyslexic to use one or other of the two kinds of "phonological reading." The third category of reading error has no such natural interpretation; and it is probably premature to attempt one, since not enough is known about just how one should describe, let alone explain, the errors of this third category. Even the putatively neutral set of terms "letter deletions, changes, additions, or position errors," while descriptively appropriate may at the same time offer a misleading view of this unexplained category of errors.

Deep dyslexia

This is the most intensively studied of the five syndromes described in this paper. Coltheart (1980a) refers to 22 cases described in detail during the period 1931 to 1979, and a recent book (Coltheart, Patterson, and Marshall, 1980) is devoted entirely to deep dyslexia.

The most striking symptom of this disorder, and one which does not occur in any other form of acquired dyslexia, is the *semantic error*: when the patient errs in attempting to read aloud a single word, his response is often a word which is semantically related to the stimulus. Numerous examples are given in Appendix 2 of Coltheart, Patterson, and Marshall (1980); other examples, from patients currently being investigated, are *her* → "woman," *blood* → "pressure," *gift* → "present," *book* → "read," and *soul* → "angel." Newcombe and Marshall (1980) present reasons for rejecting claims that such errors occur through misunderstanding the reading-aloud task, or through attempts to circumlocute or to free-associate.

A number of other symptoms are found in patients who make semantic errors in reading aloud. These include:

1. Visual errors (e.g., *gender* → "garden," *letter* → "lettuce," *moment* → "memory").
2. Derivational errors (e.g., *child* → "children," *paid* → "pay," *mastery* → "master").
3. Function-word substitutions: when a function word is wrongly read, the response is very often another function word (e.g., *for* → "and," *our* → "from," *up* → "at").
4. Words rated high in imageability are more often read aloud correctly than words rated low in imageability.
5. Reading aloud of nonwords is impossible for nearly all patients; a few are reported who could read a small percentage of nonwords.
6. The ability to decide whether printed letter-strings rhyme is abolished when these are nonwords, and impaired when they are words.
7. Content words are read correctly more often than function words.[8]
8. Writing, spontaneously or to dictation, is impaired.
9. Auditory-verbal short-term memory is impaired.

Two points need to be made about this lengthy list of symptoms. The first is that reading is by no means entirely abolished, despite the occurrence of all the symptoms: comprehension of concrete nouns can be excellent, for example, and Saffran and Marin (1977) estimated, using tests of comprehension, that their patient V. S. possessed a reading vocabulary of at least 16,500 words, even though she displayed all of the symptoms of deep dyslexia. The second point to be made is that this list of symptoms is not an assortment from which each patient displays a subset of symptoms: on the contrary, none of the reported patients who made semantic errors in reading aloud failed to display any of the nine symptoms in the list given above.

How might one explain deep dyslexia within the theoretical framework provided by Figure 1? Firstly, one clearly must propose a serious deficit in, or abolition of, the nonlexical phonological recoding component: this results in inability or near-inability to read nonwords aloud. Furthermore, if abolition of this component also causes difficulties with function words and produces derivational errors, as suggested by the characteristics of phonological dyslexia, then these two symptoms of deep dyslexia could also be explained. Many symptoms remain, however, including the most obvious one, the semantic error, plus the imageability effect, the part-of-speech effect, and the difficulty in phonological processing of words (shown by difficulty in judging whether printed words rhyme).

It follows that, if one wishes to interpret deep dyslexia as arising from the use of a damaged form of the reading system described in Figure 1, more than one of the components of this system must be damaged. Morton and Patterson (1980) offered such an interpretation in terms of multiple damage. In order to encompass all of the major symptoms of deep dyslexia, they had to postulate all of the following loci of damage:

1. The nonlexical phonological recoding component is not functional (hence nonwords cannot be read aloud).

2. The direct connections from the word recognition component to the word pronunciation component are not functional (if they were functional, all words could be read aloud, even if nonwords could not).

3. Semantic representations of abstract words in the word comprehension component are impaired. This means that, of the three routes from print to speech in Figure 1, two are impaired for both abstract and concrete words (namely, the nonlexical phonological recoding route and the direct route from word recognition to word pronunciation whilst the remaining route (via word comprehension) is impaired for abstract words. The result will be that fewer abstract words than concrete words will be read aloud correctly.

4. Communications between the word comprehension component and the word pronunciation component are impaired in such a way that, for some words, the semantic code accessed does not uniquely identify a single entry in the word pronunciation component, but instead identifies only a family of semantically related entries (and an incorrect choice from this family will lead to a semantic error). Alternatively some entries in the word pronunciation component are inaccessible: the words corresponding to these entries will thus be understood but cannot be read aloud (or, if the

patient is reluctant not to respond, he may produce a semantic error which he can identify as an error).

6. A linguistic processor, located in the word comprehension component, is impaired (hence derivational errors; and this may also explain difficulties with function words).

It is plain that to interpret deep dyslexia within the framework offered by Figure 1 is very complex, especially by contrast with the interpretation of the other acquired dyslexias described here; their interpretations do not call for many loci of impairment. This may conceivably be because much more is known about deep dyslexia than about other acquired dyslexias. An alternative and radically different possibility is that, whilst the other acquired dyslexias discussed here do reflect the functioning of a partly damaged version of the normal reading system, deep dyslexia does not. Instead, in deep dyslexia the normal reading system does not function at all, and the patient's reading is mediated by an entirely different system. This view has been argued by Saffran, Bogyo, Schwartz, and Marin (1980) and by Coltheart (1980 c): their view is that the normal reading system, located in the left hemisphere, is entirely non-functional in deep dyslexia, and that a quite different system, located in the right hemisphere, is responsible for reading in this syndrome.

A disadvantage of the claim that deep dyslexia reflects reading by a normal reading system which has suffered impairments to many components is that these components are supposed to be independent; if so, they should be independently damageable. For example, impaired representation of abstract words in the word comprehension component and impaired communications between the word comprehension component and the word pronunciation component should be independently occurring symptoms; this means that patients should exist who have the former symptom without the latter. Such patients would show as large an imageability effect on reading aloud as do deep dyslexics, but would not make semantic errors. I know of no reports of patients exhibiting this pattern of performance. Such patients may nevertheless, be observed in the future, and if they are this would strengthen the Morton-Patterson interpretation of deep dyslexia.

If deep dyslexia reflects right-hemisphere reading, the symptoms of deep dyslexic reading should tally with characteristics of right hemisphere linguistic processing; and some attempts at assessing the degree to which this correspondence holds were made by Coltheart (1980 c), who suggested that studies of normal readers might be taken to indicate the following:

1. The right hemisphere cannot derive phonology from print non-lexically.

2. The right hemisphere possesses more adequate semantics for concrete words than for abstract words.

3. The right hemisphere is liable to make semantic errors.

4. In Japanese readers, the right hemisphere is superior at dealing with the ideographic script *kanji* than the syllabic script *kana*.

A person who could only use his right hemisphere for reading would thus be unable to derive phonology from print nonlexically, would be worse at abstract words than concrete words, would make semantic errors, and (if Japanese) would read kanji better than kana. All of these symptoms occur in deep dyslexia.

A quite different line of evidence which may be used to support an interpretation of deep dyslexia in terms of right-hemisphere reading is provided by studying the nature of the lesions in the brains of deep dyslexic patients. Computerised tomographic brain scans for five deep dyslexics are reproduced in Appendix 1 of Coltheart, Patterson, and Marshall (1980). All five scans indicate extremely large left-hemisphere lesions. In other forms of acquired dyslexia, lesions may be much smaller than these.

Further details of the argument concerning deep dyslexia as right-hemisphere reading are given in Coltheart (1980 c), and will not be repeated here. Instead, two of the difficulties for this interpretation of deep dyslexia will be noted.

Firstly, as Patterson (see Coltheart, 1980c p. 353) pointed out, comparisons between letter-by-letter reading and deep dyslexia raise problems for the right-hemisphere interpretation of deep dyslexia. Letter-by-letter readers with no right-hemisphere damage should be able to use the putative right-hemisphere reading system, and this should permit prompt and accurate reading of at least some words. Instead, in letter-by-letter reading, words are read by the laborious, and often inaccurate, letter-by-letter method. If there is a right-hemisphere reading system, letter-by-letter readers would profit by using it; why don't they? A possible answer to this question emerges from considering the anatomical bases of the two disorders. It appears that in deep dyslexia there is extremely extensive left-hemisphere damage, as mentioned above. In letter-by-letter reading, it is usual for two lesions to exist: one in the left occipital region and one in the splenium (the posterior part of the corpus callosum). A traditional explanation of letter-by-letter reading is that the angular gyrus of the left hemisphere, a region crucial for reading, cannot receive input from either visual half field. Input from the right visual half field cannot occur because of the left occipital damage; input from the left visual half field cannot occur because the pathway from right occipital cortex to left angular gyrus uses the splenium. If the splenium is used generally to transmit semantic information from a right-hemisphere reading system to a left-hemisphere speech output system, damage to the splenium could prevent a reader from making use of an entirely intact right-hemisphere reading system. It would be necessary here to assume that information about individual letter identities can be transferred by some nonsplenial callosal pathway.

A more serious problem is presented by a patient described by Warrington (1981). This patient, with left-hemisphere damage, showed an imageability effect in reading aloud: but for him it was abstract words which were easy to read and concrete words which were difficult. He could read *opinion, manner, truth,* and *nature,* for example, but not *carrot, thigh, garage,* or *cheese.* If the left hemisphere can deal with both abstract and concrete words, whereas the right hemisphere can only deal with concrete words, it is easy to see how a lesion could produce a patient who can read only concrete words; but how could a lesion produce a patient who can read only abstract words? To put this another way: since this patient appeared to have an intact right hemisphere, why could he not use his right-hemisphere reading system to read concrete words?

A RÉSUMÉ

Consider first of all how the system described in Figure 1 is used for reading aloud. The first stage of processing is the accessing of the correct abstract letter identities in the ALI system, and the output of information (about letter identities) to the word recognition component and the nonlexical phonological recoding component. When such output fails to reach these two components, the only method of gaining access to higher stages of the reading system (such as the word comprehension or word pronunciation components) will then be via explicit serial naming of the letters in the letter string being inspected: this will result in the syndrome of letter-by-letter reading.

If the ALI system functions correctly and its output succeeds in reaching the word comprehension and nonlexical phonological recoding components, a defect of the latter component will mean that nonwords cannot be read aloud correctly whilst words can (this is phonological dyslexia), whilst the opposite defect – correct functioning of nonlexical phonological recoding with a defect of access to, or exit from, the word comprehension component – will result in surface dyslexia, in which there is extensive reliance on the nonlexical reading route even for lexical items for which the lexical route is normally available.

An inability to access entries in the word comprehension component will not, in terms of Figure 1, affect reading aloud: it will only affect reading comprehension.

Consider next how the system described in Figure 1 is used for reading *comprehension*: here what is needed is access to the correct entry in the word comprehension component. In letter-by-letter reading such access cannot be achieved in the normal way via the word recognition component. It is achieved instead by just the method that an intact subject would use when asked to make judgements about the meanings of words which are spelled out to him. In phonological dyslexia, since it is proposed that the lexical route is intact and that the only damage is to the component responsible for nonlexical phonological recoding, reading comprehension should be intact.

Comprehension in phonological dyslexia has been studied by Patterson (in press: patient A. M.). This patient's performance at matching pictures to printed words, and at judging whether pairs of printed words were synonymous or not, was good, as was his performance in lexical decision tasks (even with function words or abstract words). However, reading comprehension for single printed words did not seem to be entirely intact: there appeared to be comprehension difficulties for certain function words, and there were derivational errors in comprehension. The latter kind of error was demonstrated by showing that A. M. made errors when asked to choose which of two derived forms of the same root morpheme was the one which fitted correctly into a sentence frame. These results suggest that we may need to conclude, from studies of phonological dyslexia, that the nonlexical phonological recoding component of Figure 1 has a part to play in reading comprehension, and this would be a particularly clear example of the way in which neuropsychological data can be used to indicate ways in which models of normal reading may require revision or extension.

In surface dyslexia, since "phonological reading" is used so extensively, comprehension will often be achievable only by using phonological representations to access the word comprehension component. This will happen whenever access to the correct entry in the word recognition component fails, or when it succeeds but communication from the word recognition to word comprehension component fails. In these circumstances regular non-homophonic words may be comprehended correctly from print, because their phonological representations can be encoded correctly by nonlexical phonological recoding and are unambiguous. On the other hand, homophonic words whose phonological representations are ambiguous may be mutually confused in tests of comprehension of printed words; irregular words, which will be assigned incorrect phonological representations by nonlexical phonological recoding, will sometimes therefore not be comprehended correctly.

If there is impairment to the word comprehension component, then, of course, comprehension of the printed word (and the spoken word) will be reduced or abolished, even though reading aloud may be intact (the unnamed dyslexia).

This summarises how one might interpret the characteristics of oral reading and reading comprehension in four acquired dyslexias (letter-by-letter reading, phonological dyslexia, surface dyslexia, and an unnamed dyslexia), using the same approach to all four. This approach consists of starting off from the model described in Figure 1, then indicating for each disorder which components are intact and which are impaired, and finally attempting to show how the particular pattern of deficits and preservations proposed should yield the particular set of symptoms observed.

The fifth acquired dyslexia described in this paper, deep dyslexia, appears not to be amenable to this approach; I have argued that a different kind of account is needed for this syndrome. The view I have taken is that one cannot account for the symptoms of this syndrome in terms of a pattern of deficits and preservations of the components of the model shown in Figure 1. Instead, it is suggested that deep dyslexic reading is accomplished by a quite different system – a system located in the right hemisphere. If this is so, then one cannot use deep dyslexia as a tool for investigating the nature of the normal reading system, as one can use the other acquired dyslexias. On the other hand, one may be able to use deep dyslexia as a tool for investigating the nature of right-hemisphere linguistic processing. In the limit, if the right-hemisphere account of deep dyslexia were correct, then testing the reading of a deep dyslexic would be equivalent to testing the reading of the right hemisphere of a split-brain patient, with the advantage that in deep dyslexia language lateralisation may be assumed to have occurred normally (since there was no preadolescent brain damage) whereas in the split brain patients abnormal lateralisation is very likely (since in most of these patients there was brain damage dating from infancy). Thus the right hemisphere of the deep dyslexic may be comparable to the normal right hemisphere, whilst the right hemisphere of the split-brain patient may not.

1. In this situation the term "abstract visual code" is sometimes used, the claim being made that a comparison of abstract visual codes would allow the response "Same" to DENGAR/dengar. This use of the term "abstract visual code" is, however, logically incoherent. It may well be that an abstract code could be used to identify D with d; but surely there is no sense in which this code is *visual.* The adjective "abstract" here conveys the idea that the code is *not* tied to some physical modality such as sound or vision, but is abstracted away from concrete physical representation.

2. Occasionally one finds that the term "name code" seems to be used in such a way that it is not synonymous with "phonological code." This seems to me a misuse of the term "name," and in fact Posner has used, as a synonym for "name code," the term "phonetic code" (Posner and Rodgers, 1978). I therefore treat "name code" and "phonological code" as synonymous.

3. If "Different" pairs are chosen randomly, there will obviously be a high correlation between visual similarity and homophony/nonhomophony, and so a high degree of accuracy might be achieved using visual criteria. This confounding can be avoided by judicious choice of "Different" pairs, as in the example above: the degree of visual similarity between SO and SEW is identical to the degree of visual similarity between NO and NEW. Thus use of visual criteria with such stimuli could not produce above-chance accuracy: using phonological codes is the only way to succeed.

4. Many letters (e.g., C O U I etc.) are very similar in their uppercase and lowercase forms. For these letters, matching across case might be a visual process. We avoided this possibility by constructing all our nonword stimuli from the letters GARDE and N; for these six letters, uppercase and lowercase forms are quite dissimilar.

5. Of course, one could judge that A and a are the same by using letter names; but if one assumes, as is assumed in Figure 1, that when letters are named they must first be assigned correct ALIs, then correct letter naming implies that the ALI component is functioning correctly. Therefore, even if cross-case matching of letters or non-words uses letter names rather than letter identities, intact performance on this task indicates intactness of the ALI component in Figure 1.

6. This assumption would certainly not be accepted by all of those to whom a model of the form shown in Figure 1 is congenial. It might well be argued, for example, that the word comprehension component is involved when lexical decisions are made. The occurrence of semantic priming effects in lexical decision tasks does not demand this, however, since feedback from the word comprehension component to the word recognition component could account for such effects even if lexical decisions are made solely by monitoring the word recognition component.

7. *Route* and *root* are homophones in British English.

8. It has been claimed in the past that even within the category of content words, there is a part-of-speech effect, nouns being read better than adjectives, which are read better than verbs. However, since there is a correlation between part of speech and imageability/concreteness, the previous work on this subject, which has not balanced imageability/concreteness across the different parts of speech, is unsatisfactory. Allport (personal communication) has selected a set of nouns and a set of verbs matched on imageability. This material has been administered to four deep dyslexics so far: and none has shown worse performance with verbs than with nouns.

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