Varieties of developmental dyslexia*

Anne Castles and Max Coltheart
School of Behavioral Sciences, Macquarie University, North Ryde, NSW 2109, Australia

Received September 2, 1991, final version accepted December 28, 1992

Abstract


This paper reviews and evaluates the evidence for the existence of distinct varieties of developmental dyslexia, analogous to those found in the acquired dyslexic population. Models of the normal adult reading process and of the development of reading in children are used to provide a framework for considering the issues. Data from a large-sample study of the reading patterns of developmental dyslexics are then reported. The lexical and sublexical reading skills of 56 developmental dyslexics were assessed through close comparison with the skills of 56 normally developing readers. The results indicate that there are at least two varieties of developmental dyslexia, the first of which is characterised by a specific difficulty using the lexical procedure, and the second by a difficulty using the sublexical procedure. These subtypes are apparently not rare, but are relatively prevalent in the developmental dyslexic population. The results of a second experiment, which suggest that neither of these reading patterns can be accounted for in terms of a general language disorder, are then reported.

Introduction

Many reading disorders are produced by brain damage. These disorders are usually referred to as acquired dyslexias and are distinguished by the fact that the individuals concerned were previously competent readers but suffered an impair-

*This work was supported by an Australian Postgraduate Research Award, and was presented at the Experimental Psychology Conference in Sydney in 1992. We thank the staff of Queenscliff Diagnostic Unit, Manly; Westmead Hospital Learning Disabilities Clinic, Parramatta; and St. Patrick's College, Strathfield, for providing us with the subjects for this study. We are also grateful to Karalyn Patterson for comments on early drafts of the paper.

Correspondence to: Anne Castles, Department of Psychology, University of Melbourne, Parkville, Victoria 3052, Australia.
ment of that ability due to brain injury. However, reading disorders are also found in people who have never sustained any brain damage. In these cases, the individuals have not lost their ability to read, but for some reason never attained it in the first place. Disorders of this kind may be referred to as developmental dyslexias.

Beyond this rather simple distinction, it has proven extremely difficult to provide a definition of developmental dyslexia or to draw any firm conclusions about its nature. The disorder was first discussed intensively under the term congenital word blindness at the turn of the century (Hinshelwood, 1917; Pringle Morgan, 1896). At this time, and for many years afterward, the tendency was to treat the disorder as a unitary syndrome, with a single underlying cause. Numerous attempts were made to isolate single factors which could account for the symptoms of the entire disordered population (e.g., Denckla & Rudel, 1976; Orton, 1937). Not surprisingly, these attempts were largely unsuccessful. More recently, increasing support has been gained for the view that developmental dyslexics do not form a homogenous population, but rather fall into a number of distinct subgroups (Boder, 1973; Mattis, French, & Rapin, 1975; Mitterer, 1982). While there is still some controversy about the nature of the divisions, it is now generally agreed that there are several different types of developmental dyslexia (Marshall, 1984).

Since acquired dyslexias also come in a number of different forms (Marshall & Newcombe, 1973; Patterson, 1981), some researchers have been prompted to examine what relationship (if any) might exist between these disorders and the developmental dyslexias (Baddeley, Ellis, Miles, & Lewis, 1982; Coltheart, Masterson, Byng, Pryor, & Riddoch, 1983; Holmes, 1973; Marshall, 1984; Temple & Marshall, 1983). The various forms of acquired dyslexia have been found to be consistent with theoretical frameworks of the normal adult reading system (Coltheart, 1981a; Newcombe & Marshall, 1981). Therefore, if these same frameworks are applicable to the development of reading, patterns of reading should be found in developmental dyslexia which are analogous to those found in acquired dyslexia. It is this proposal which has formed the focus of this study.

The dual-route model of reading

We will begin by outlining a model of the skilled adult reading process and describing the way in which that model has been applied to acquired reading disorders. Many theorists have advocated a dual-route model of reading aloud (e.g., Coltheart, 1978; Morton & Patterson, 1980); they believe that the system which skilled readers use to read involves at least two separate procedures, one often referred to as the lexical procedure and the other as the sublexical procedure. Reading aloud via the lexical procedure involves retrieving, from a mental lexicon, the phonological form appropriate to a particular orthographic
Developmental dyslexia

stimulus. Since, by definition, the mental lexicon contains only representations of real words which the reader has previously encountered, this procedure is unable to read nonwords, like fot. Reading aloud via the sublexical procedure involves using correspondence rules which specify relationships between submorphemic orthographic and phonological segments (e.g., grapheme-phoneme conversion rules). Pronunciations are "assembled" from smaller orthographic components. The problem with this procedure is that it produces incorrect responses for irregular or exception words, like yacht, as these words disobey the correspondence rules. Therefore, to be a skilled reader, an individual needs to be able to use both the lexical and the sublexical reading procedures.

Besides the dual-route model, there exist two other prominent accounts of the process of reading aloud. The first, known as the multiple levels model (Shallice & McCarthy, 1985), argues for the existence of intermediate units between the word-level and grapheme level units described above. While this model represents a significant elaboration of the dual-route framework, it continues to postulate the existence of some form of grapheme-phoneme conversion procedure and some form of word-level recognition procedure, and so does not challenge the basic distinctions drawn in the dual-route model.

The second, more radical alternative to the dual-route model is the single-route or analogy model (Glushko, 1979; Marcel, 1980; Seidenberg & McClelland, 1989). According to this model, there is a single procedure for reading aloud which can successfully translate both exception words and nonwords from print to speech. It was difficult to evaluate this claim until a computationally explicit version of this type of model was developed by Seidenberg and McClelland (1989). Once this was done, it was possible to investigate quantitatively just how well a model of this type could read aloud both exception words and nonwords, and perform other tasks which had hitherto been regarded as being explicable only in dual-route terms, such as lexical decision. Besner, Twilley, McCann, and Seergobin (1990) showed that the Seidenberg and McClelland model was much poorer than people are at reading nonwords aloud, and also at lexical decision, so the model does not provide a good account of these aspects of skilled reading.

Furthermore, the symptom patterns displayed by some acquired dyslexics have provided support for the dual-route model over the single-route model, in that they appear to reflect specific damage to one or the other of two distinct reading-aloud procedures. Firstly, there are reports of subjects who can read aloud regular words and nonwords, but have difficulty with irregular words (Behrmann & Bub, 1992; Bub, Cancelliere, & Kertesz, 1985; Coltheart et al., 1983; Marshall & Newcombe, 1973; Patterson, Marshall, & Coltheart, 1985). The errors that these subjects make are of a distinctive type, known as regularisation errors: irregular words are pronounced according to traditional grapheme-phoneme conversion rules, such as yacht as /yatʃt/ (Bub et al., 1985). This pattern of symptoms, referred to as surface dyslexia, is exactly what we would expect to find if there had been selective damage to the lexical procedure for
reading aloud. In contrast, other subjects have been described who can read aloud both regular and irregular words, but cannot read nonwords (Beauvois & Derouesne, 1979; Patterson, 1982; Shallice & Warrington, 1980). This specific difficulty with nonword reading, referred to as phonological dyslexia, would appear to reflect damage to the sublexical procedure for reading aloud. The model of Seidenberg and McClelland (1989), which does not distinguish between lexical and sublexical procedures, has not succeeded in offering an account of these two forms of acquired dyslexia.

Hence at present the dual-route framework appears to be superior to other frameworks as a way of accounting for a variety of facts about skilled reading and acquired dyslexia. However, it is by no means a foregone conclusion that developmental reading disorders will be equally compatible with this framework. Acquiring a skilled reading system and then losing some component of it as a result of brain damage is somewhat different from never having acquired that system in the first place. It may be the case that a completely different theoretical framework is required for the developmental dyslexias. However, as Coltheart (1987) notes, learning to read must involve acquiring the dual-route system in some sense, for only after both reading procedures are mastered is one a normally skilled reader. Therefore, it is possible that developmental reading disorders might reflect a particular difficulty in acquiring one or the other of the two reading procedures in the process of learning to read and that, consequently, the symptom patterns displayed will be similar to those found in acquired surface and phonological dyslexia. To explore this possibility further, we need to know something about the process by which children are believed to learn to read.

*Phases of reading development*

Several theorists have proposed that children pass through a series of phases when learning to read (Frith, 1985; Marsh, Friedman, Welch, & Desberg, 1981; Seymour & MacGregor, 1984). Frith (1985) has proposed that there are three of these phases: the logographic phase, the alphabetic phase and the orthographic phase. During the logographic phase, children are said to acquire a small sight vocabulary of words, which they have learned to recognise immediately. Salient graphic features are often used as cues in this recognition process (e.g., a child may recognise the word *yellow* because it has two “tall sticks” in the middle). However, as the number of words to be learned increases, this strategy becomes progressively less effective (the strategy for recognising *yellow* is no longer useful once the word *follow* also has to be recognised). Later, children enter the alphabetic phase, where, having acquired some phonetic knowledge, they begin to attempt to read words using letter-to-sound correspondences. This phase, which could be said to be comparable with the operation of the sublexical procedure, is
very useful, as it allows children to pronounce (though not necessarily correctly) words which they have not seen before. Finally, during the orthographic phase, children learn to read words as orthographic units, without phonological conversion. Unlike in the logographic phase, this recognition process is not purely visual or cue based, but relies on the rapid recognition of internally represented abstract letter-by-letter-strings (most probably in the form of morphemes). This final phase of reading development, therefore, could be said to correspond to the operation of the lexical procedure.

Frith (1985) suggests that developmental dyslexics might be arrested in this sequence of development either at the alphabetic phase or the orthographic phase. In the first instance, words which were in the child's restricted sight vocabulary could be read aloud, but novel words or nonwords could not. The symptoms, therefore, would be somewhat similar to those displayed by acquired phonological dyslexics. In the second instance, words could be read aloud when they obeyed rules which the child had learned, but not when the spelling-to-sound relation was irregular (unless, of course, the word was contained in the limited sight vocabulary developed during the logographic phase). In this case, the symptoms would correspond to some degree with those of acquired surface dyslexics.

Therefore, current theories of the acquisition of reading are not inconsistent with the suggestion that developmental reading disorders might be analogous to those observed in the acquired dyslexic population. It seems that, as children learn to read, they do in a sense acquire the dual-route system. We will now review some empirical evidence, in the form of intensive individual case studies of developmental dyslexics, which has provided further support for this proposal.

Support for the comparability of developmental and acquired dyslexias

Cases of developmental surface dyslexia

Holmes (1973) was the first to point out the similarity between the symptoms displayed in certain cases of developmental dyslexia and those of acquired surface dyslexics. This finding has since been supported and expanded on by Coltheart and his colleagues (Coltheart et al., 1983). Their patient, CD, was a 17-year-old girl with an IQ exceeding 100 but a reading age of only 10 years. Her reading performance closely resembled that of acquired surface dyslexics in that she was more successful at reading aloud regular words than irregular words and made frequent regularisation errors. The authors attributed her performance to a selective difficulty in using the lexical procedure and so justified the use of the term developmental surface dyslexia to describe her condition. Job, Sartori,
Masterson, and Coltheart (1984) have described a similar case of developmental surface dyslexia in Italian.

Cases of developmental phonological dyslexia

In contrast to this, Temple and Marshall (1983; Temple, 1984) have described a putative case of developmental phonological dyslexia. Their patient, HM, was also a 17-year-old girl of average intelligence and with a reading age of around 10 years. Her reading, however, showed a quite different pattern from that of CD. She could read aloud both regular and irregular words quite well, but performed very poorly on nonwords and rare words. Often, her responses to the nonwords contained word components, suggesting that she used real word analogies in attempting to pronounce them. She made none of the regularisation errors observed in CD’s reading. On the basis of these symptoms, the authors concluded that HM had a specific difficulty in using the sublexical procedure and that her condition was therefore analogous to acquired phonological dyslexia. Another similar case has been reported (Campbell and Butterworth, 1985), and Sartori and Job (1982) have described a case of developmental phonological dyslexia in Italian.

At this point, the argument in favour of a close correspondence between the developmental and acquired dyslexias might seem quite convincing. However, several researchers have strongly criticised the proposal, both on methodological and theoretical grounds.

Arguments against the comparability of developmental and acquired dyslexias

Dissociating developmental surface and phonological dyslexia

Wilding (1989) has argued that none of the developmental dyslexics so far described has shown a complete dissociation on the critical error categories. That is, none has produced errors only to irregular words in the case of surface dyslexia or only to nonwords in the case of phonological dyslexia. Rather, all of the subjects have displayed some inefficiencies on both procedures. For this reason, he argues, assignment of these cases to particular syndrome categories is inappropriate.

Examining Coltheart et al.’s (1983) developmental surface dyslexic, CD, Wilding notes that, while her regular word reading was superior to her irregular word reading, suggesting reliance on the sublexical route, three other symptoms indicated use of the lexical procedure. Firstly, her nonword reading was far from perfect. An adequately functioning sublexical procedure should not have pro-
duced this result. Secondly, her matching of homophones was worse for nonwords than for regular words. This is not what we would expect to happen if CD was reading both types of words via the sublexical procedure. Finally, half of the errors CD made to nonwords were words, suggesting that she may have been reading lexically by matching the nonwords with the closest visual analogues in her sight vocabulary. Wilding concedes that it is possible that this third symptom was produced by CD responding with the closest acoustic matches after having sounded the nonwords out sublexically, but argues that the promptness of her responses makes this possibility unlikely.

Turning to the developmental phonological dyslexics, Wilding notes that all of the cases described have possessed some phonics skills in addition to their whole-word skills. Temple and Marshall's (1983) patient, HM, was able to read 39% of nonwords correctly and Campbell and Butterworth’s (1985) patient could read 64% correctly. In both cases, this was actually more than could be read by CD (who was correct on only 31% of nonwords overall). Therefore, Wilding concludes that it is misleading to label these patients in such a way as to imply that the operation of their sublexical routes is significantly worse than those of the developmental surface dyslexics. Developmental surface and phonological dyslexia, he goes on to argue, cannot be dissociated and the fundamental weakness in all of the subjects is related to phonological processing (see also Marcel, 1980).

Exception can be taken to Wilding's arguments on a number of grounds. Firstly, if our approach is correct, we would not expect to find very many developmental dyslexics who could use only the lexical procedure or only the sublexical procedure. In fact, if Frith's (1985) theory of the stages of reading development is an appropriate one, children will almost always have some words in their sight vocabulary before they begin to acquire phonics skills. Rather than completely failing to develop one of the two procedures, it is far more likely that a developmental dyslexic will have acquired both procedures to some degree but that, for some reason, one process will be operating less efficiently than the other, producing either a surface or a phonological dyslexic pattern. Therefore, the fact that CD appeared to be using the lexical route on some occasions and HM the non-lexical route does not undermine the concept of using these dimensions as a basis for comparison.

Secondly, Wilding's demonstration that some of the reported cases of developmental phonological dyslexia displayed phonics skills which were as good as or better than those of the developmental surface dyslexics does not necessarily imply that the two skills are not dissociable. It can be argued that what is important when we are using a model-based approach is the relative functioning of the lexical and sublexical procedures within a particular individual. Comparison across subjects of the absolute levels of functioning of one or the other of the two procedures is less significant, for, as has been noted, in most cases both will be operating to some degree. The key point is that a patient whose phonics skills are
at 50% and whose sight vocabulary is at 90% has a different problem from one whose phonics skills are also at 50% but whose sight vocabulary is at 10%.

It would seem that many of Wilding’s criticisms are founded on a somewhat outdated syndrome-based approach to the study of dyslexia. He is certainly correct when he notes that developmental dyslexics rarely make errors only on nonwords or only on irregular words. But the same is true of the acquired dyslexic population (see, for example, Ellis, 1985). Many theorists now agree that dyslexics, whether they are developmental or acquired, do not fall into homogeneous subgroups and that the concept of placing them into distinct categories is misguided (Coltheart, 1984; Ellis, 1985). As Ellis notes, within each syndrome category there are often functionally heterogeneous patients, as the same symptoms can be produced by problems with a number of different processes. Further, between each syndrome category, distinctions are often blurred and the process of drawing dividing lines is somewhat arbitrary. Thus, Wilding is certainly justified in criticising an approach which focuses on placing dyslexics in discrete, non-overlapping syndrome categories.

However, this criticism does not, as Wilding seems to assume, necessarily undermine the validity of making comparisons between the acquired and the developmental dyslexias. A more recent approach to studying the acquired dyslexias, which we have described, has been to use a model of the skilled reading process to predict and account for differences in the observed behaviour of dyslexics (Coltheart, 1984; Ellis, 1985). What is important is not the name of the syndrome, but the presence of symptoms which reflect the level of functioning of some component of the system. If, as has been proposed, children are acquiring that system when they learn to read, they should show errors which can be accounted for by the model in the same way that acquired dyslexics do. Therefore, there will be similarities between acquired and developmental dyslexics, not because the syndromes are the same, but because the same model is relevant to both. Wilding does not appear to take account of this possibility.

**Functional deficits versus use of “strategies”**

A second, related criticism of the case studies, raised by Wilding (1989) as well as others (e.g., Snowling, 1987), is that the studies do not take adequate account of differences in the use of strategies by subjects. Wilding (1989) states:

> Researchers rarely discuss the type of teaching experienced by their subjects or ask subjects how they attempt to pronounce individual words. To interpret a particular [reading] pattern as due solely to a particular functional deficit without considering reading strategy is to ignore many of the relevant factors. (p. 110)

Wilding goes on to conclude that all the cases of developmental dyslexia so far described can be explained in terms of weaknesses in phonological processing,
“combined with differences in the strategies adopted to cope with this” (p. 126). Snowling (1987) makes a similar statement, arguing that the dyslexic profile of an individual is the result of an interaction of the degree of phonological difficulty, the relative efficiency of visual and semantic processes and “the readiness to switch to these alternatives” (p. 143). For example, a patient with a severe phonological impairment but good visual processing may choose the strategy of reading lexically and therefore show the phonological dyslexic pattern, while a patient who also has a phonological impairment but who has a poor visual processing system as well may select the non-lexical procedure and show a surface dyslexic pattern.

The term “strategy” appears to have been used by these theorists in a rather loose way. It can be applied, it seems, to any or all of a large range of factors which might possibly affect an individual’s reading performance on a particular occasion, including educational background, situational constraints, personality factors and motivational issues. The only characteristic holding these various factors together is that they are perceived as being entirely distinct from and unrelated to basic cognitive processes. Weaknesses which can be explained by differences in “strategy”, it seems, can in no way shed light on the nature of the underlying cognitive processes involved in reading.

It would seem to be necessary for these theorists to specify exactly what they mean when they attribute the absence of particular skills to differences in “strategy”. Are they referring to skills which an individual simply has not acquired, or to skills which an individual has acquired, but for some reason does not demonstrate on a particular occasion? At present, both types of skill seem to have been included under the same banner: educational background, for example, is surely a factor which would result in the former condition, while situational or motivational factors might produce the latter.

Whichever of these options is chosen, there is a further issue concerning the degree to which strategies can be separated from basic cognitive processes. If we are to include in our definition of strategies those skills which, due to educational deprivation or other factors, an individual has never properly acquired, then surely we are not talking about skills which are separable from and unrelated to basic processes. On the contrary, the two may well be linked in a causal fashion: lack of educational experience in a particular area, for example, may be the causal factor which has resulted in an individual’s basic reading system developing in a particular way. If, on the other hand, we are to include in our definition only those skills which an individual has acquired but which he or she has chosen not to use, there still appear to be unavoidable links with basic processes. An individual cannot choose to use a “strategy” unless the basic cognitive process which allows him or her to demonstrate that strategy is functioning. Therefore, although the individual may choose not to exhibit it on all occasions, a strategy, when it is used, is an indisputable indicator of the functioning of a certain basic
process. Certainly, it would be wrong to conclude, when an individual does not demonstrate a skill on a particular occasion, that the associated basic process is not and never will be functioning. However, when it is demonstrated, a strategy is nothing more than a basic process in action.

To summarise, while educational, situational and motivational factors must certainly be included in any worthwhile debate on reading, it seems misguided to treat these factors as something separable from and in opposition to the basic processes. As Ellis (1985) points out, the basic processes tell us how an individual is reading, but not why he or she is reading that way. In many cases, it is just these other factors which can be used to shed light on the causes of particular reading patterns.

Comparing developmental dyslexics with normal readers

Another strong criticism of the case studies as they presently stand has come from Bryant and Impey (1986), who argue that the value of these studies is seriously diminished by the fact that no comparisons were made with normal readers. Their point is that, regardless of how far an individual's reading age lags behind his or her chronological age, that individual's reading cannot be regarded as abnormal unless the reading pattern differs from that shown by young normal readers. If a developmental dyslexic displays a reading pattern which is the same as that of reading-age-matched (not chronological-age-matched) controls, then all that has been demonstrated is that the former is indeed a retarded reader - something that we presumably knew anyway. We cannot, they argue, draw any conclusions about the nature of the underlying functional architecture.

On this premise, Bryant and Impey selected 16 children of normal reading ability, who were matched on reading age with Coltheart et al.'s (1983) developmental surface dyslexic, CD (i.e., about 10 years). They then administered to these children the same battery of tests which had been given to CD. Bryant and Impey found that there was little difference between the reading test scores for the normal children and the scores which had been obtained for CD. The children mispronounced as many irregular words and homophones as CD, and their errors included an equal number of regularisation and stress errors. Bryant and Impey therefore concluded that there was nothing abnormal about the surface dyslexic symptoms observed in CD because these symptoms were shared at least as strongly by children of normal reading ability.

Bryant and Impey's argument can be questioned on a number of grounds. Firstly, as Coltheart (1987) points out, it seems strange to suggest that there is nothing abnormal about a 17-year-old girl who reads at a 10-year-old level. Surely, a seven year lag in reading age must be considered abnormal in some sense, even if the pattern of reading does not deviate from that of reading-age-
matched controls. A delay as great as this, Coltheart argues, implies the presence of a defect in some processing system, which in itself requires explanation.

Secondly, the demonstration by Bryant and Impey that the symptoms of surface dyslexia can be found in young normal readers does not necessarily challenge the validity of the cases of developmental dyslexia which have been described. In fact, in their paper, Coltheart et al. (1983) actually predicted that this would be the case. Their point, expanded on by Coltheart (1987), is that the symptoms shown by developmental dyslexics can be interpreted as reflecting the fact that one of the two reading procedures is being used less effectively than the other. In the case of developmental phonological dyslexia, the sublexical procedure is being used less effectively; in the case of developmental surface dyslexia, the lexical procedure is being used less effectively. There is no reason why normal children, as they are learning to read, should not acquire one of the two procedures more quickly than the other and therefore show similar symptoms. In fact, as has been discussed, Frith’s (1985) stages of reading development imply that this will often be the case.

When their logic is examined more closely, Bryant and Impey also seem to be confusing symptoms with causes. The essence of their argument is that, since CD’s symptoms are not abnormal, they cannot be used to “explain” her reading difficulties. However, as Coltheart (1987) points out, a subject’s symptoms can never be used to explain his or her difficulties: the symptoms are what are to be explained in the first place. If one wishes to know what causes a particular pattern of symptoms, one must look elsewhere, not at the symptoms themselves.

A valuable inference which can be drawn from Bryant and Impey’s study is one which, ironically, was suggested initially by Coltheart and his colleagues (1983). It seems that it may be appropriate to differentiate between (a) whether an individual’s reading is abnormal, and (b) whether his or her reading pattern is qualitatively different from that of young normal readers. The former question can be addressed by using chronological-age-matched controls. This will establish whether a particular reader should be regarded as a developmental dyslexic. The latter can be investigated by using reading-age-matched controls. This second type of control will establish whether the form of dyslexia displayed by the individual corresponds to delay or deviance. In cases of delay, the reader has simply failed to progress beyond the normal early phases of reading; in cases of deviance, the reader has demonstrated patterns of reading which do not correspond to any of the normal reading stages.

**Can the functional architecture be the same?**

The preceding criticisms have tended to focus on the case studies of developmental dyslexia as they presently stand and, in particular, on the validity of any
comparisons made with acquired dyslexics. However, at a more fundamental level, some theorists have suggested that it is not theoretically justifiable even to attempt such comparisons. The same underlying functional architecture, it is argued, cannot logically be applicable to both developmental and acquired disorders (Ellis, 1985; Wilding, 1989).

The basis of this argument lies in the fact that acquired and developmental dyslexics are essentially different: acquired dyslexics have attained a skilled reading system and then lost some component of it as a result of brain damage, while developmental dyslexics have never acquired that system in the first place. If it were the case that our brains contained hard-wired neural units specifically developed for the purpose of reading, this would not pose a problem. Developmental dyslexia could be explained in terms of a failure of some pre-existing component of the system to begin functioning, in the same way that acquired dyslexia would be explained in terms of a loss of functioning in that same component. However, it is very unlikely that the brain has in fact developed systems specific to reading. In evolutionary terms, written language is an extremely recent acquisition (about 5000 years old), and even today is used by only a limited proportion of the population (Ellis, 1985). It is far more likely, therefore, that learning to read involves the adaptation of neural systems which have been evolved for far more general cognitive purposes (Wilding, 1989). This being the case, why would we expect to see the selective deficits that are apparent in acquired dyslexics in developmental dyslexics?

Ellis (1985) expands on this point. It seems, he notes, that in the process of becoming a skilled reader, the brain gradually allocates some of its general cognitive powers specifically to the task of reading. We know that this must be the case, because when skilled readers sustain brain injuries, we can observe highly selective impairments to the reading process, such as those described in cases of acquired dyslexia. However, where developmental dyslexia is concerned, that allocation process has not yet taken place, so we would not expect to see such specific impairments. Rather, he claims, we would expect to observe deficits in processes which are necessary for learning to read, but which are not specific to it. In the case of developmental phonological dyslexia, this might take the form of subtle problems with manipulating the spoken forms of words; in the case of surface dyslexia, it might involve a visual memory deficit.

There is undoubtedly some truth to this argument. Firstly, it is difficult to dispute the fact that the dual-route system of reading is unlikely to be represented in our brains in the form of hard-wired neural units. (For one thing, if this were the case it would be difficult to explain why children can learn to read either alphabetic or syllabic or logographic writing systems, depending on the culture in which they were born.) Secondly, there is growing evidence to suggest that reading disorders in children are associated with deficits of cognitive processes that are not specific to reading, such as phonological or visual memory problems
Developmental dyslexia

(e.g., Campbell & Butterworth, 1985; Goswami & Bryant, 1990; Snowling, 1987; Vellutino, 1979). However, to conclude, on the basis of this, that selective reading deficits will never be present in developmental dyslexics and that the dual-route model of reading is inapplicable to them seems unjustified.

As has been argued, learning to read must involve acquiring the dual-route system in some sense, for only after both reading procedures are mastered is one considered a normally skilled reader (Coltheart, 1987). If an individual has, for some reason, a particular difficulty in acquiring one or the other of these procedures, his or her reading pattern will reflect this: the individual will be unusually poor at reading either irregular words or nonwords. This will be true even if the reason for the difficulty is some factor outside the specific domain of reading. For example, an individual might have difficulty learning to read via the lexical procedure, and therefore show deficits on irregular word reading, because his or her visual memory skills are poor. Viewed this way, there seems no reason why we should not expect to find developmental dyslexics with specific reading disorders, even if these disorders are related to other cognitive deficits and not to failures of specialised neural components. The dual-route model, which represents the system which all readers must ultimately attain, would seem to be a most appropriate theoretical framework for defining these individuals.

THE PRESENT STUDY

In summary, while there has been much controversy surrounding the issue, the argument in favour of the existence of distinct varieties of developmental dyslexia, analogous to those found in acquired dyslexia, remains quite powerful. The careful application of a model of the skilled reading process has made many of the criticisms raised against the proposal seem less convincing. Further, the approach has been supported by the empirical evidence of individual case studies.

An obvious next step is to build upon this empirical base. In particular, research involving larger samples of developmental dyslexics, matched carefully with normal controls, would have a bearing on many of the empirical and theoretical questions raised thus far. Firstly, it would permit a thorough search for incidences of double dissociations between developmental surface and phonological dyslexics, which, if demonstrated, would serve to challenge scepticism about the validity of the existing case studies of developmental dyslexia (e.g., Wilding, 1989). Secondly, it would allow some empirical examination of claims by Bryant and Impey (1986) that the reading patterns shown by developmental dyslexics do not deviate from those of young normal readers. If we were to demonstrate opposing reading patterns in significant numbers of children of exactly the same reading age, their argument would be difficult to sustain: are Bryant and Impey to claim that both surface and phonological reading patterns are typical of normal
readers of that age? Thirdly, the identification of a substantial number of developmental dyslexics with specific difficulties using either the lexical or the sublexical procedure would undermine suggestions by some theorists (e.g., Ellis, 1985) that the same functional architecture cannot logically be applied to both developmental and acquired reading disorders.

Perhaps most importantly, a large sample study would help to determine the clinical relevance of the present approach to developmental reading disorders. While the developmental dyslexics described in the few existing case studies have shown a clear pattern of symptoms, we do not know, as Wilding (1989) and others (e.g., Seymour, 1986) have pointed out, what proportion of the subjects which have been examined by researchers have shown such a clear pattern, let alone what proportion of the whole population. Therefore, we cannot draw any conclusions about whether these cases are relatively rare or whether they represent a substantial proportion of the developmental dyslexic population. Research involving larger samples, instead of individual case studies, is needed to resolve this issue and to determine the theoretical and clinical value of the present approach to developmental reading disorders. Some research of this form is reported in Experiment 1.

EXPERIMENT 1

Method

Subjects

There were 112 subjects altogether: 56 dyslexic subjects and 56 control subjects. The dyslexic subjects were 56 children (all male) selected on an availability basis from remedial reading classes and learning disabilities clinics in Sydney. Females were also tested when they were available, but their numbers proved to be so small that they were excluded from the sample (4 females out of 60 children tested). The boys ranged in age from 8 years 6 months to 14 years 11 months (mean age = 11 years 2 months). All were extremely delayed readers: their reading ages were at least 18 months behind their chronological ages (mean delay = 35 months; range = 18 months to 78 months). Further, as all were within the normal IQ range (mean IQ = 97; range = 85–119), their reading ages were also delayed with respect to IQ. None of the subjects had any history of neurological illness or damage.

As the children were recruited from various centres, it was not possible to derive all of their reading age and IQ scores from the same tests. Many of the centres had already completed these assessments using their preferred tests. However, all of the children included in the sample had been examined with
well-standardised reading and IQ tests, no longer than 3 months prior to the testing date. The reading age scores came from either the Neale Analysis of Reading, the Woodcock Reading Mastery Test or the Gap Reading Comprehension Test (McLeod, 1965). The IQ scores were derived from either the Wechsler Intelligence Scale for Children, Revised (WISC-R), the Stanford-Binet Intelligence Test or Raven’s Progressive Matrices, Standard Form.

The control subjects were 56 boys from two Sydney schools. All were normal readers: their reading ages had been measured by the Woodcock Reading Mastery Test or the Gap Reading Comprehension Test as falling within 6 months of their chronological ages. The boys ranged in age from 7 years 6 months to 14 years 0 months, reflecting the chronological age range of the dyslexic subjects. Specifically, there were 10 children from each of the school years: 3, 4, 5, 6, 7 and 8. (Four subjects were removed from the sample due to inconsistencies in their reading age scores.)

**Materials**

A test battery was compiled which would allow separate assessment of the functioning of the lexical and sublexical reading procedures. A set of irregular words was included in the battery to allow examination of the lexical procedure and a set of pronounceable nonwords to assess the functioning of the sublexical procedure. Regular words were also included in the battery, for the purposes of comparison with the irregular words.

The battery consisted of 90 stimuli altogether: 30 regular words, 30 irregular words and 30 pronounceable nonwords (the stimuli and word frequency information can be found in the Appendix). Norms from the Medical Research Council (MRC) Psycholinguistic Database (Coltheart, 1981b) were used to match the regular and irregular words on frequency and imageability. The matched pairs of words were also of the same grammatical class and consisted of the same number of letters. Therefore, if a subject read fewer irregular words correctly than regular words, it was possible to conclude that this was due to a deficit in lexical reading skills and not to other differences between the lists. The 30 pronounceable nonwords were constructed so as to represent various levels of orthographic complexity, as described by Hornsby and Shear (1976), ranging from mono-syllabic three-letter strings through to bisyllabic six-letter strings. The 90 words and nonwords were printed onto cards (lower case, Geneva, 14 point).

Where a composite score was not available, the Word Identification subtest of the Neale and the Accuracy subtest of the Woodcock were used, as these were considered the most appropriate for the present purposes. Both permitted the calculation of a reading-age score.
Procedure

Testing took place over a period of 8 months. The children were tested individually, in sessions which lasted approximately 15 min. Each child was seated opposite the experimenter in a quiet room and asked to read aloud the words and nonwords, which were presented to him on cards. Before the cards were presented to the subject, he was given the following instructions:

I am going to show you some cards. Each card has a word printed on it and I want you to read out loud what the word says. Some of the words you might find easy and some of them you might find hard. You are not expected to know all of them. Sometimes, the words will not actually be real words, but nonsense words that I have made up (show them one). I want you to try and read these just like the other words. OK?

If the children appeared confused, the instructions were repeated. The subjects then proceeded to read aloud the words and nonwords, presented to them one at a time and in random order. No feedback on correctness of responses was given. There were no time limits placed on the children and error data only were recorded.

Results

Total correct scores (/30) for regular word reading, irregular word reading and nonword reading were calculated for each child in both the control and dyslexic groups. Some of the children in the dyslexic group had scores which were so low for all stimulus types that any comparison between the types would have been impossible. For this reason, three subjects, who were unable to obtain a score of more than 5/30 for any of the three stimulus types, were excluded from further analysis. Means and standard deviations of the reading scores for the control and dyslexic groups are presented in Table 1.

Before the results for the dyslexic group could be analysed, it was necessary to form a picture of the normal development in children of the reading of irregular words and nonwords, based on the performance of the control subjects. Simple regression analyses of (a) irregular word reading as a function of chronological age, and (b) nonword reading as a function of chronological age, were performed

\(^1\)Correct responses for the nonwords were determined according to the correspondence rules given in Venezky (1970). However, in the case of inconsistent nonwords, such as *gead*, a response that consisted of the use of a clear, but less frequent correspondence rule than the one specified by Venezky was not counted as an error.

\(^2\)Split-half reliability checks were carried out for the regular, irregular and nonword lists. For the regular list, \(r = .848\); for the irregular list, \(r = .837\); and for the nonword list, \(r = .896\).
Table 1. Means and standard deviations of regular, irregular and nonword reading scores for the control and dyslexic groups

<table>
<thead>
<tr>
<th></th>
<th>Control group</th>
<th>Dyslexic group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regular</td>
<td>Irregular</td>
</tr>
<tr>
<td>Control group</td>
<td>27.9 (2.7)</td>
<td>18.1 (3.5)</td>
</tr>
<tr>
<td>Dyslexic group</td>
<td>20.4 (5.9)</td>
<td>11.3 (4.1)</td>
</tr>
</tbody>
</table>

on the 56 control subjects. As would be expected, there was a highly significant relationship between age and irregular word reading, $F(1, 54) = 59.53, p < .0001$, with age accounting for 52% of the variance in irregular word reading. Examination of the residuals revealed that this relationship did not deviate from linearity. Figure 1 contains a plot of the data, with the line of best fit added (slope = .122; intercept = 2.645).

The second simple regression analysis revealed a similar relationship between age and nonword reading. Again the relationship was highly significant, $F(1, 54) = 18.497, p < .0001$, with age accounting for 25% of the variance in nonword reading. Examination of the residuals again revealed no evidence of deviation from linearity. The data, with their line of best fit (slope = .103; intercept = 11.118), are presented in Figure 2.

As there were clear linear relationships in both cases, these estimates of the normal progression of reading in children could be used as the basis for the

![Figure 1. Irregular word reading by the control group.](image)
selection of those subjects in the dyslexic sample who were particularly poor for their age at (a) irregular word reading, and (b) nonword reading. Upper and lower confidence limits, which identified the points beyond which only 5% of scores would be expected to fall, were established for both irregular word reading and nonword reading. These limits were used as the criteria for the selection of aberrant scores in the dyslexic group. Scores which fell outside these limits were outside the range in which 90% of the scores of the control subjects fell.

The scores for 40 out of the 53 dyslexic subjects fell below the lower confidence limit for irregular word reading. Thus, by this criterion, 75% could be classified as abnormal for their age in their ability to read irregular words. The irregular word reading scores for the dyslexic subjects, and the confidence boundaries, are presented in Figure 3.

For nonword reading, the scores for 38 out of the 53 subjects (72%) were found to be below the lower confidence limit for nonword reading. These findings are presented in Figure 4.

More importantly for the present purposes, 18 out of the 53 subjects (34%) fell below the lower confidence limits for one of the tasks, but within the limits for the other. Ten subjects were outside the range for irregular word reading, while they fell within the range for nonword reading. In 6 out of these 10 cases, the subjects’ nonword reading scores were not only within the limits, but fell within one standard deviation of the expected score for their age. Eight subjects showed precisely the reverse pattern: their scores fell within the range for irregular word reading, but outside it for nonword reading. Again, in the majority of these cases (5/8), the subjects’ irregular word reading scores fell within one standard deviation of that expected for their age.
A further confirmation of the validity of these results was sought by examining the subjects' regular word reading scores. As described, the 30 regular words were carefully matched with the 30 irregular words, such that any deficits in irregular word reading scores should have been attributable to deficits in lexical skills rather than to extraneous factors. Therefore, we would expect the difference
between regular and irregular word reading scores to be greater for the 10 surface dyslexic subjects, who supposedly have poor lexical skills, than for the control subjects. This proved to be the case: the mean difference in regular and irregular word scores for the controls was 9.8, while the mean difference for the dyslexics was a significantly higher 14.4, $t(64) = 4.529$, $p < .0001$. For the 8 phonological dyslexics, on the other hand, the difference between regular and irregular word reading scores should have been less than that of the controls, since their lexical skills are supposedly not affected, but they are unable to use sublexical skills to assist their regular word reading. The mean difference between regular and irregular word reading scores for the phonological dyslexics was 7.75, which tended towards being less than, but did not differ significantly from, that of the control subjects, $t(62) = 1.817$, $p = .074$.

As well as identifying those dyslexic subjects who were normal at one of the tasks and abnormal at the other, we wished to isolate those subjects who were poor at both tasks, but who were markedly worse at one task than the other. These subjects, too, could be classified as showing a dissociation between irregular word reading and nonword reading. Again, the results of the control subjects were used for this purpose. A simple regression of irregular word reading score on nonword reading score was performed for the 56 control subjects, so as to permit estimation of the expected number of nonwords to be read correctly at varying levels of irregular word reading, and vice versa. The analysis revealed a significant relationship between irregular word reading and nonword reading, $F(1, 54) = 24.181$, $p < .0001$. The results are presented graphically in Figure 5. A

![Graph](image)

Figure 5. Irregular word by nonword reading for the control group.

As even normal readers may not have perfect lexical knowledge, we would expect to find some difference between regular and irregular word reading scores even in the control subjects.
second analysis was performed to examine whether the effects of age might account for this relationship. However, when age was introduced as a covariate, the critical relationship between irregular word reading and nonword reading remained significant, partial $r = .319; p < .05$.

Predicted values based on this linear relationship were used to identify those subjects in the dyslexic group who were performing markedly below expectations on one task, based not on their age but on their performance on the other task. Ninety percent confidence intervals were again established for both (a) nonword reading based on irregular word reading scores, and (b) irregular word reading based on nonword reading scores. The confidence limits and the results for the dyslexic subjects are presented in Figure 6.

The results of this analysis revealed that 16 out of the 53 dyslexic subjects (30%) were below the lower confidence limit for irregular word reading, when predictions were made from their nonword reading performance. That is, these
subjects were much poorer at reading irregular words than would have been expected on the basis of their nonword reading scores (even though, in some cases, they were below average at both tasks). Conversely, 29 subjects (55%) fell below the lower confidence limit for nonword reading when predictions were made from their irregular word reading scores. These subjects were much poorer at reading nonwords than would have been expected on the basis of their irregular word reading performance.

In summary, 45 out of the 53 dyslexic subjects (85%) appeared to show a dissociation between their irregular word reading performance and their nonword reading performance. (This figure represents the total number of subjects identified in the second analysis, as all those identified in the first, age-based, analyses were included within this group.) Eighteen out of these 45 cases (or 34% of the total sample) were within the normal range for their age at one task, while they fell below the lower 5% limit for the other task. In the remainder of the cases (51% of the total sample), the subjects were below average at both tasks, but were markedly worse at one task than at the other.

The majority of the 45 subjects exhibiting a dissociation showed a phonological dyslexic pattern: their nonword reading skills were inferior to their irregular word reading skills. Twenty-nine subjects (55% of the total sample) showed this pattern, with 8 of these subjects (15% of total sample) exhibiting normal-range irregular word reading scores for their age. However, a significant number showed the reverse, surface dyslexic, pattern: 16 subjects (30% of the total sample) showed irregular word reading skills which were inferior to their nonword reading skills, with 10 of these subjects (19% of total sample) actually falling within normal range for their age at nonword reading.

Discussion

The results of this initial study appear to provide evidence for the existence of two distinct varieties of developmental dyslexia, the first of which is characterised by a deficit in whole word recognition (or in the use of the lexical procedure) and the second by a deficit in letter-to-sound rules (or in the use of the sublexical procedure). These specific reading disorders were found not to occur only in isolated instances, as has been suggested to be the case by some researchers (e.g., Wilding, 1989), but were identified in a large proportion of the developmental dyslexics studied. In total, 85% of the subjects showed a dissociation between their irregular word reading performance and their nonword reading perform-

\footnote{It is worth noting that there were incidences of children who had come from the same school and who had been exposed to identical remedial teaching regimes but who displayed opposite patterns of developmental dyslexia. This would seem to suggest that, although educational background may play a part in these results, it cannot account fully for the variations in reading pattern reported.}
ance. As would be expected, in many cases, these subjects were below average at both skills but were simply worse at one skill than the other. However, about one third of the subjects studied (34%) were normal for their age at one task, while they fell below the lower 5% confidence limit on the other task. Considering that all of these children had reading ages at least 18 months behind their chronological ages, this would seem to be a substantial figure.

Importantly, the dissociations demonstrated between irregular word reading and nonword reading were not always in the same direction. Sixty-four percent of those subjects displaying a dissociation showed a phonological dyslexic pattern (poor nonword reading), while the remaining 46% showed a surface dyslexic pattern (poor irregular word reading). If this had not been the case, it would have been possible to argue that all developmental dyslexics are of the one general type and that one of the tasks was simply more difficult for the subjects than the other. The finding that a substantial proportion of dyslexic subjects displayed each of the two opposing patterns adds further weight to the proposal that these patterns reflect distinct varieties of developmental dyslexia.

However, closer examination reveals a potential problem with the data, which is related to this issue. Though unlikely, it is possible that the children who were poor at whole word recognition (i.e., those who showed a surface dyslexic pattern) were demonstrating a disorder not specifically related to reading processes. That is, these children may not have been able to read irregular words well because they were not familiar with those words in spoken language. A language deficit, rather than a reading disorder per se, may have been responsible for their distinctive reading patterns. This being the case, the data from Experiment 1 may not in fact have distinguished two subtypes of developmental dyslexia, but may instead have isolated one form of developmental dyslexia (a difficulty applying letter-to-sound rules) and a second, unrelated language disorder. It was thought necessary to examine this possibility in a supplementary experiment.

**EXPERIMENT 2**

The purpose of Experiment 2 was to confirm that poor word reading and, particularly, poor irregular word reading in developmental dyslexics actually reflects a specific reading disorder and cannot be attributed to a general spoken language deficit. Fortunately, a clear means of distinguishing between these two possibilities was available to us: we simply needed to test developmental surface dyslexic children's auditory comprehension of the words that they had been unable to read. If a language disorder accounts for the deficit in their irregular word reading, then that same deficit should also be found in their comprehension of irregular words, when those words are presented to them orally. They should be poorer at comprehending irregular words than regular words, in the same way
that they were poorer at reading them. If, on the other hand, their irregular word
deficit is due to a specific reading disorder, we would not expect to find any
difference in their auditory comprehension of the matched regular and irregular
words.

**Method**

**Subjects**

The subjects were 20 children (all male) from a remedial reading class in a Sydney
school. The children ranged in age from 10 years 4 months to 12 years 5 months
(mean age = 11 years 5 months). As with Experiment 1, all the boys had
measured reading ages which were at least 18 months behind their chronological
ages (mean delay = 30 months; range = 18 months to 58 months). However, all
were within the normal IQ range (mean IQ = 100; range = 86–119) and none had
any history of neurological disorder.

**Materials**

The 30 regular words and 30 irregular words in the battery described in Experi-
ment 1 were used to assess the reading and auditory comprehension of the
children.

**Procedure**

In order to identify those children in the sample who were of particular interest –
that is, those who had difficulty with reading irregular words – it was necessary to
test the children’s reading of the regular and irregular words, in addition to testing
their auditory comprehension of those words. For this reason, the subjects were
required to perform two tasks: (a) reading out loud the regular and irregular
words, and (b) demonstrating comprehension of the same set of words, when
those words were spoken to them. The order in which subjects performed these
tasks was counterbalanced.

The procedure for the reading phase was exactly the same as for Experiment 1. In
the comprehension phase, the subjects were required to demonstrate some
knowledge of the meaning of the words in the test battery, either by providing a
definition of them or by placing them in a sentence. The words were presented to
them orally, one at a time, and in random order. In the case of homophonic
words, extra prompting was given. For example, if the child responded to the
word *break* with “a brake on a car”, he was asked, “Can you think of any other meaning for that word? It might have a different spelling.” After testing had been completed, five adult volunteers were asked to rate the accuracy of the children’s definitions.

**Results**

Total correct scores (/30) for regular and irregular word reading were calculated for each of the 20 subjects. As children with a specific difficulty reading irregular words were of particular relevance here, those dyslexic subjects displaying this problem were selected from the group for analysis. The 90% confidence limits developed in Experiment 1 were used to identify these children, of which there were 12, as can be seen from Figure 7. The judgements of the raters were then used to calculate total correct scores for these 12 children’s regular and irregular word comprehension.⁶

Analysis of mean reading scores for this subgroup revealed that these children were indeed much poorer at reading the irregular words than the matched regular words. Their mean reading score for regular words was 21.9 (SD = 6.5), while for irregular words it was 10.5 (SD = 3.4). This difference was highly significant (*t*(11) = 11.417, *p* < .0001). However, there was no significant difference in the

![](image)

**Figure 7.** Irregular word reading by 20 dyslexic subjects, with 90% confidence limits shown.

⁶Their definitions were scored as correct if three or more out of the five raters had marked them as adequate. However, it should be noted in 99% of cases the raters were unanimous in their decision about the adequacy of the definitions.
mean comprehension scores for the regular words ($M = 20.8$, $SD = 2.2$) and the irregular words ($M = 21.5$, $SD = 1.7$), $t(11) = 0.667$, $p = .3225$.

Thus, it appears that poor irregular word reading in developmental dyslexics cannot be accounted for in terms of a general language deficit. The children in this study whose reading of irregular words was far inferior to their reading of regular words showed no differences in their auditory comprehension of the two types of words. Had a general language disorder accounted for their reading problems, we would have expected to find a pattern in their comprehension scores which was analogous to that which we had found in their reading scores. Instead, we found auditory comprehension scores which were equivalent across word types.

**GENERAL DISCUSSION**

It would appear that developmental dyslexics do not form a homogeneous population. The results reported here support the notion that a clear double dissociation exists between surface and phonological dyslexic reading patterns, with some children displaying a specific difficulty reading via the lexical procedure in the absence of any difficulty with the sublexical procedure and others showing precisely the reverse pattern. Further, neither of the disorders observed in the developmental dyslexics can be attributed to a general language deficit: those children who have particular difficulty reading certain words do not generally have the same difficulty comprehending those words when they are presented to them auditorily.

Further, in response to questions raised by Wilding (1989), it would seem that these reading patterns are not rare phenomena, but are quite prevalent in the developmental dyslexic population. Approximately one in three children who present with reading disorders can be expected to have a particular difficulty with one reading procedure in the absence of any difficulty with the other. Many more children can be expected to have difficulties with both procedures, in varying degrees of severity. As disorders of this kind may be found in a substantial proportion of the developmental dyslexic population, it would seem appropriate for clinicians to focus carefully on the functioning of the lexical and sublexical procedures when assessing and treating reading disorders in children.

Scepticism by some theorists (e.g., Wilding, 1989) about the existence of completely pure cases of developmental dyslexia would also seem to be challenged by the present findings. Wilding has argued that none of the cases of developmental dyslexia so far reported has shown a clear dissociation on the critical error categories of irregular word reading and nonword reading. Rather, the subjects have been able to perform both tasks to some degree and diagnoses have been made on the basis of relative superiority on one task over the other,
without any consideration of absolute levels of performance. He argues that:

The clearest cases [of developmental dyslexia] would be where, on some agreed set of stimuli which normal readers of the same age can read, (a) nonword reading is accurate and irregular word reading is very poor (surface dyslexia), or (b) nonword reading is very poor and irregular word reading is accurate (phonological dyslexia). (p. 109)

This is precisely the pattern of results that we were able to demonstrate in the present study. Many examples were found of children who fell well within the normal range for their age on one skill while they were extremely poor on the other. While, for reasons discussed in the introduction, the total absence of one of the reading procedures in these subjects would be expected to be quite rare, pure cases of developmental dyslexia certainly seem to exist in the reading-disordered population.

From a theoretical, as well as a clinical and methodological perspective, the present findings have some important implications. Firstly, the results would seem to provide support for a dual-route model of the reading process (e.g., Coltheart, 1978; Morton & Patterson, 1980), as opposed to the parallel-distributed-processing model of Seidenberg and McClelland (1989). The surface and phonological reading patterns observed in the developmental dyslexics provide clear developmental analogues to the reading patterns observed in the acquired dyslexic population (e.g., Bub et al., 1985; Patterson, 1982). Together, these patterns suggest that various components of the reading system are indeed functionally separable from one another. In the case of acquired dyslexia, specific components of the system have been separately damaged; in the case of developmental dyslexia, specific components of the system have, for some reason, not been properly acquired. In both cases, the relevant theoretical framework would seem to involve a modular, rather than a distributed, conceptualisation of the normal adult reading system.

Secondly, suggestions by Ellis (1985) that the same functional architecture cannot logically be applied to both developmental and acquired reading disorders would also appear to be unfounded. Ellis has argued that, as children have not yet attained a skilled reading system, they cannot logically lose a component of that system. Therefore, selective deficits in reading should not be demonstrable in developmental dyslexics. However, a substantial proportion of the dyslexic children in the present study were found to have highly selective deficits in reading. Ellis, it seems, has not considered the possibility that failure to develop a particular component of the reading system, for whatever reason, might produce the same pattern of symptoms as damage to that same component (especially if the other components of the system are developing normally). The key point, as Coltheart (1987) has suggested, is that there is a particular set of skills which a child must acquire in order to become a skilled reader and that they are the same skills which are sometimes damaged in acquired dyslexia. A single theoretical framework, which represents all of these skills, is relevant in both cases.
Bryant and Impey (1986) used reading-age-matched controls to support their argument that there is nothing abnormal about the symptoms displayed by developmental dyslexics. These symptoms, they claim, are shared at least as strongly by children of normal reading ability. Aside from the theoretical objections which can be raised to this proposal (Coltheart, 1987), the present findings would appear to provide some empirical refutation. In the present study, performance on the lexical and sublexical procedures of normal children of various ages was carefully charted. The reading of developmental dyslexic children was then assessed on the basis of these chronological age norms. Thus, our primary emphasis was on documenting the presence of delay in various aspects of the reading of developmental dyslexic children. However, while we did not directly compare the dyslexics with their reading-age-matched controls, there were also clear examples of deviance. Many double dissociations were found between developmental dyslexic children of the same reading age; that is, some of these children had difficulty using the sublexical procedure in the absence of difficulty with the lexical procedure, while others of the same reading age had the reverse problem. While more detailed comparisons need to be made between these children and their reading-age-matched controls, it is clear that both reading patterns could not possibly be considered normal for children of this reading age.

Having identified these specific reading patterns in developmental dyslexic children, an obvious next step is to determine what might be the cause of them. As Coltheart (1987) has pointed out, the symptoms we have described tell us how a particular individual is reading, but not why he or she is reading in that manner. Some advances have been made in answering this latter question in the case of difficulty acquiring the sublexical procedure. There is a large body of evidence to suggest that this particular type of reading difficulty is associated with a low level of phonemic knowledge (e.g., Freebody & Byrne, 1988; Goswami & Bryant, 1990). Further, Olson and his colleagues (Olson, Wise, Conners, Rack, & Fulker, 1989) have provided evidence that it also has some genetic component. However, in the case of difficulty acquiring the lexical procedure, very little is currently known and further research is clearly required to examine this question.

In conclusion, close examination of the symptom patterns displayed by a large group of developmental dyslexic children, and the assessment of these patterns according to a model of the normal reading process, has helped to resolve many of the questions surrounding the issue of varieties of developmental dyslexia. That there do exist distinct varieties of developmental dyslexia, and that these varieties are relatively prevalent in the developmental dyslexic population, seems difficult.

---

Olson and his colleagues studied the identical twins of children with reading difficulties and found that, if the original child had poor sublexical skills, the likelihood that the child’s twin would also have a reading difficulty was high. However, if the original child had poor lexical skills, there was no more likelihood that the twin would have a reading difficulty than would an unrelated child.
to refute. Those undertaking further research in this area, therefore, may benefit from shifting their focus away from deliberations about the existence or otherwise of various types of developmental dyslexia and towards the important task of investigating the possible causes of these disorders.

References


**Appendix: The test battery**

**Words**

<table>
<thead>
<tr>
<th></th>
<th>Regular</th>
<th>Frequency*</th>
<th>Irregular</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>take</td>
<td>611</td>
<td>come</td>
<td>630</td>
</tr>
<tr>
<td>2</td>
<td>free</td>
<td>260</td>
<td>sure</td>
<td>264</td>
</tr>
<tr>
<td>3</td>
<td>market</td>
<td>155</td>
<td>island</td>
<td>167</td>
</tr>
<tr>
<td>4</td>
<td>effort</td>
<td>145</td>
<td>answer</td>
<td>152</td>
</tr>
<tr>
<td>5</td>
<td>plant</td>
<td>125</td>
<td>blood</td>
<td>121</td>
</tr>
<tr>
<td>6</td>
<td>middle</td>
<td>118</td>
<td>pretty</td>
<td>107</td>
</tr>
<tr>
<td>7</td>
<td>check</td>
<td>88</td>
<td>break</td>
<td>88</td>
</tr>
<tr>
<td>8</td>
<td>drop</td>
<td>59</td>
<td>lose</td>
<td>58</td>
</tr>
<tr>
<td>9</td>
<td>luck</td>
<td>47</td>
<td>soul</td>
<td>47</td>
</tr>
<tr>
<td>10</td>
<td>navy</td>
<td>37</td>
<td>iron</td>
<td>43</td>
</tr>
<tr>
<td>11</td>
<td>chicken</td>
<td>37</td>
<td>colonel</td>
<td>37</td>
</tr>
<tr>
<td>12</td>
<td>context</td>
<td>35</td>
<td>routine</td>
<td>35</td>
</tr>
<tr>
<td>13</td>
<td>wedding</td>
<td>32</td>
<td>ceiling</td>
<td>31</td>
</tr>
<tr>
<td>14</td>
<td>smog</td>
<td>1</td>
<td>quay</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>tail</td>
<td>24</td>
<td>bowl</td>
<td>23</td>
</tr>
<tr>
<td>16</td>
<td>victor</td>
<td>23</td>
<td>regime</td>
<td>23</td>
</tr>
<tr>
<td>17</td>
<td>weasel</td>
<td>1</td>
<td>meringue</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>mist</td>
<td>14</td>
<td>shoe</td>
<td>14</td>
</tr>
<tr>
<td>19</td>
<td>infest</td>
<td>1</td>
<td>indict</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>curb</td>
<td>13</td>
<td>pint</td>
<td>13</td>
</tr>
<tr>
<td>21</td>
<td>nerve</td>
<td>12</td>
<td>gauge</td>
<td>12</td>
</tr>
<tr>
<td>22</td>
<td>pump</td>
<td>11</td>
<td>tomb</td>
<td>11</td>
</tr>
<tr>
<td>23</td>
<td>peril</td>
<td>8</td>
<td>choir</td>
<td>8</td>
</tr>
<tr>
<td>24</td>
<td>radish</td>
<td>8</td>
<td>debris</td>
<td>8</td>
</tr>
<tr>
<td>25</td>
<td>brandy</td>
<td>7</td>
<td>cough</td>
<td>7</td>
</tr>
<tr>
<td>26</td>
<td>stench</td>
<td>1</td>
<td>brooch</td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>ditty</td>
<td>1</td>
<td>beret</td>
<td>0</td>
</tr>
</tbody>
</table>
Words

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regular</td>
<td>Frequency*</td>
<td>Irregular</td>
<td>Frequency</td>
</tr>
<tr>
<td>28.</td>
<td>marsh</td>
<td>4</td>
<td>yacht</td>
<td>4</td>
</tr>
<tr>
<td>29.</td>
<td>flannel</td>
<td>4</td>
<td>bouquet</td>
<td>4</td>
</tr>
<tr>
<td>30.</td>
<td>cord</td>
<td>6</td>
<td>wolf</td>
<td>6</td>
</tr>
</tbody>
</table>

Nonwords

1. gop
2. teg
3. nad
4. lif
5. sut
6. stet
7. mulp
8. prin
9. nint
10. gren
11. thim
12. chut
13. sith
14. phot
15. giph
16. hoil
17. toud
18. gead
19. doil
20. roin
21. gurdet
22. torlep
23. radlen
24. latsar
25. polmex
26. tashet
27. sothep
28. miphic
29. lishon
30. dethix

*Based on norms from the MRC Psycholinguistic Database (Coltheart, 1981b).