Temple, C.M. (1997). Developmental Clinical Neuropsychology. East Sussex, UK: Psychology Press.

CHAPTER FIVE

Reading Disorders

HISTORICAL PERSPECTIVES: THE GLASGOW VIEW

In 1877, Kussmaul coined the term word-blindness to refer to acquired disorders of reading resulting from brain damage. Kussmaul had noticed that "a complete text-blindness may exist, although the powers of sight, the intellect and the powers of speech are intact."

Nineteen years later, Morgan (1896) adopted the term word-blindness to refer to cases of reading disability which occur developmentally as a selective impairment and without recognisable aetiology. He modified the term to incorporate the developmental aspects and referred to these disorders as *congenital word-blindness*. It was not simply the adoption of similar terminology that suggested a relationship between the two groups of reading disorders. At the end of the 19th century, the similarities between the behavioural format of the reading disorders of acquired and congenital word-blindness were described. Word without letter-blindness was described within both congenital word-blindness and acquired word-blindness (Dejerine, 1892; Kerr, 1887). It was known that the angular gyrus was damaged in many cases of acquired word-blindness, and in 1910, Fisher speculated that a congenital aplasia of the angular gyrus might underlie problems in learning to read. Thus, not only were cognitive aspects associated with the expression of the acquired and developmental disorders postulated to be similar but a similarity in underlying neurological substrate was also postulated.

Morgan (1896) described a 14-year-old boy who was bright and intelligent and good at games. He was of a similar intellectual level to the other children of his age but had specific difficulty in learning to read. He had by constant application learnt to know what letters were, but though at school for seven years and though he had persistent remedial help, he could only with difficulty spell out words of one syllable. Written or printed words conveyed no instant impression to him and it was only after laboriously spelling them that he was able, by the sounds of the letters, to discover the identity of the word. In this description, the boy resembles contemporary cases within the adult neurological literature of acquired letter-by-letter reading. The boy's schoolmaster said that he would have been one of the most intelligent children in the school if his instruction had been entirely oral. Thus, in this early description, Morgan emphasises the good intelligence of the child and the selective impact of the disorder.

Both acquired and congenital word-blindness were studied in detail by James Hinshelwood, a surgeon at the Glasgow Eye Infirmary and a lecturer on ophthalmology in the Glasgow Western Medical School, who worked at the end of the 19th and in the earlier part of the 20th century. Following a series of publications in the *Lancet,* Hinshelwood (1900a) published his book on acquired word-blindness, which described the distinct disorders of letter-, word-, and mind-blindness. This taxonomic classification system was based upon the performance of the patients when attempting to read. In this regard, Hinshelwood's formulations and methodology resemble those of contemporary neuropsychology. Although Hinshelwood was concerned about the anatomical substrates to the different components involved in the reading process, he also discussed in some detail his conceptual formulation of visual word memory and the visual word centre. Seventeen years later, in 1917, Hinshelwood published his book on congenital word-blindness. In the foreword to this book he noted that he had:

> devoted considerable space to the subject of acquired word-blindness, without an adequate knowledge of which, in my opinion, congenital word-blindness cannot be properly understood. My aim has been first to furnish the reader with the chief facts regarding acquired word-blindness and then to employ this knowledge in the interpretation and explanation of the various phenomena of congenital word-blindness.

Within the text of the book Hinshelwood made his thesis even more explicit:

> the complex processes involved in vision proceed smoothly and harmoniously during health in the region of the unconscious cerebration, but when disease disturbs the delicate mechanisms of the brain, there are revealed to us glimpses of its intimate working, a knowledge of which we would not acquire otherwise. It is for this reason that we have studied at such length the symptoms of acquired word-blindness, the knowledge of which will enable us to interpret and explain the phenomena of the congenital form. An adequate knowledge of the former condition is an essential preliminary to the proper understanding of the latter. (p. 40)

Hinshelwood's interest in congenital word-blindness pre-dated the publication of his congenital word-blindness book. Within a fortnight of Morgan's publication in 1896 of the description of the 14-year-old child with congenital word-blindness, Hinshelwood had published a critical. note about the paper explaining some of the symptoms in the light of his studies with acquired word-blindness. Morgan was already aware of Hinshelwood's work and in private correspondence with Hinshelwood had pointed out that:

> it was your paper — may I call it your classical paper? — on word-blindness and visual memory published in **1895,** which first drew my attention to the subject, and my reason for publishing this case was that there was no reference anywhere, so far as I knew, to the possibility of the condition being Congenital.

Hinshelwood's first report of his own cases of congenital word-blindness came in 1900 (1900b) and he attempted not only to record the cases but also to analyse and explain the symptoms. Five further cases were described by Nettleship in 1901 and two further by Hinshelwood in 1902. By 1903, interest had spread to the continent and there were case reports in different languages.

Hinshelwood (1917) proposed a three-stage model of learning to read. He pointed out that his comments refer to his "old-fashioned" (p. 53) method of learning to read which he distinguished from more recent training on "look and say" systems. The first stage in the old method was to store up in the memory, the individual letters of the alphabet. It was by comparison with this permanent visual image of the letters and the words in the cerebral centre that Hinshelwood proposed we were able to recognise printed letters and words on the pages of a book. He argued that in normal circumstances, this first stage was accomplished with comparative ease since there are only 26 letters in the alphabet, or taking both capitals and small letters, 52 visual images in all to be acquired. Thus, Hinshelwood dealt with the issue of recognition of different cases by postulating two different sets of recognition systems that are acquired for upper and lower case letters. (He did not discuss the issue of how handwriting and other permutations and alterations of the standard format are recognised.)

Hinshelwood was aware that normally we learn to read material which relates to words which we have already learnt in oral form. He proposed that the memory for words is first registered in our auditory memory centre which he located in the temporal sphenoidal lobe. This was proposed to have close connections with the visual memory centre and strong interconnections with other centres involved in language.

Traditional instruction in reading at this time involved reciting the individual letters involved in words and Hinshelwood argued that we are able to spell words before we are able to recognise them by sight. When the individual has stored up both the visual memories of the individual letters of the alphabet, in the left angular gyrus, and the spelling ofwords, in the auditory centre, then the individual can proceed to the second stage of reading. This formulation clearly differs from our contemporary ideas, in which although we expect that some abstract letter identification system has become established before we are able to read; it is not expected that we are able to spell words. Hinshelwood emphasised letter-by-letter analysis within the second stage ofreading. He argued that in this stage, words are read by spelling them aloud letter-by-letter and appealing to auditory memory to identify the word. However, he also pointed out that sometimes children are simply seen to move their lips, spelling silently each letter, and appealing, in his view, to the memory of speech movements or glosso-kinaesthetic memory. Alternatively, the child may trace the letters with his fingers on the table and appeal to memory of the kinaesthetic movements of writing.

Contemporary formulations of reading development tend to emphasise the mastery of individual sounds associated with specific letters. In Frith's (1985) model this alphabetic phase is the second stage of reading development. In the preceding model of Marsh, Friedman, Welch, and Desberg (1981), it is the third stage ofreading development. In these formulations, there is a letter-by-letter analysis but the processing of the word comes from combining the individual sounds. Hinshelwood appears to be referring to individual letter names but there is some ambiguity in his description. It is possible that one of the three aspects he described at this stage is a form of sounding out. However, he also proposed alternatives to access the word's identification by appealing to either speech movements or the writing centre. These modes only appear in contemporary models, in descriptions of circumventory strategies adopted by acquired dyslexics to bypass their fundamental reading disorder. Contemporary remedial systems attempting to improve children's reading difficulties also often

incorporate multi-modal aspects associated with reading despite the absence of the other modalities in the models of normal child acquisition. In Bradley's remedial spelling system there is the involvement of speech movements, spelling aloud, and kinaesthetic hand movements (Bradley, 1980).

Hinshelwood considers his third stage in reading development to be the hardest and to require a longer period of acquisition than the preceding stages. He described it as "a formidable task" (p. 54). The third stage in Hinshelwood's model involved the acquisition and storage of visual memories for words and this involved not reading or analysing by individual letters, but recognising each word as a separate picture. In this formulation, Hinshelwood was suggesting that in order to identify a word, it is not necessary to evoke the sound characteristics associated with the word prior to activation of its meaning. Such a stage of formulation of phonological activation prior to meaning extraction is evident in many reading models in the 1960s and 1970s. However, Hinshelwood's formulation ties in more closely with the formulations proposed in the late 1970s and 1980s in which it is possible to recognise and identify a word prior to identifying the sound characteristics associated with it.

In relation to this recognition process, Hinshelwood suggested each word is regarded as an idiogram, picture, or symbol that suggests a particular idea. This conception of the evocation of an idea seems close to what we would consider to be the activation of an item within the semantic system. According to Hinshelwood, a word is recognised at this stage just as an individual would recognise a landscape or a familiar face, by its general outline and form without resolving it into its constituent details. This emphasis upon the outline and form activating an idea, comes close to aspects of contemporary models in which input logogens or word recognition systems activate semantic systems or face recognition units access personal identity information. Thus, Hinshelwood proposed that when we look at words we compare them with abstract visual word memories of symbolic form, which suggest particular ideas. He explicitly stated that there is no need for further appeal to the auditory memory or writing centres. By Hinshelwood's final stage in reading development, the reader has attained the power to read by sight alone.

Hinshelwood pointed out that there are individual differences in the efficiency with which we acquire this final stage of reading and that there are differences in reading speed, with some people able to skip over the pages of a book with great rapidity and ease and others only able to proceed slowly and with effort. Although he considered that practice and training may be relevant to these differences, he also suggested fundamental congenital distinctions between people and argued (Hinshelwood, 1917) that the degree of development of the visual memory centre may be relevant: "We are not all furnished at the start of life with visual memories of the same capacity, and this influences us more or less throughout our whole existence'' (p.55).

Since, in his other work and discussions, Hinshelwood emphasised the distinctions between visual memory for different kinds of material such as words, letters, and numbers (see Chapter **7)** it is unlikely that in this discussion he is referring to a generalised visual memory process. Rather, since the discussion occurs at the end of a paragraph discussing visual word memories, one could argue that he is suggesting individual differences in this aspect of memory processes.

Hinshelwood described a series of cases of congenital word-blindness and then attempted to explain the symptomatology which they displayed in relation to his model of reading development. Case three, in which a child had taken nine months to acquire the letters of the alphabet, following persistent effort from his mother, was interpreted as a difficulty in acquiring the first stage of reading acquisition. It was interpreted as a grave defect in the visual memory centre, since there had been difficulty in acquiring the registration, even for the 26 basic letters (or 52 if one includes upper and lower case). Hinshelwood pointed out that most of the cases observed with congenital word-blindness are able to acquire basic letter identification skill and have difficulty with a later stage in reading development.

Hinshelwood emphasised that for most of his children auditory memory was good. In this regard, he placed very different emphasis upon the congenital reading disorders than is seen in current analyses. In the 1990s, studies tended to emphasise potential phonological processing disorders associated with developmental reading disorders (see later discussion). The only case for which Hinshelwood described specific difficulty in spelling out words, despite mastery of the identity of most of the letters, is a case where reading instruction has been based on "look and say". In this mode of reading instruction, Hinshelwood emphasised that individual letter spellings were not taught. However, since the child was able to identify individual letters but not spell them out, we may perhaps assume that there is an aspect associated with sounding out which reflects a deficiency of instruction. Hinshelwood argued that whereas for most normal children it would not be problematic if they were not taught these explicit letter spellings, since they have good visual memories and they may acquire reading by this means, for children who have weakened visual word memories, aspects of auditory processing become more critical.

Hinshelwood described a remedial system for the boy who had been taught "look and say" which is consistent with current phonemic remedial ventures. He was to be taught to spell and then to read simple words by spelling them out letter-by-letter and appealing to his auditory memory. According to Hinshelwood (1917), if there is a case of a defective visual centre but other cerebral centres are intact, the method of instruction which will be most successful is to appeal to centres other than the visual:

> this condition is fulfilled by the old-fashioned method of learning to read, in which simultaneous appeal is made to visual centre, auditory centre and the centre for the memory of speech movements. **(p. 105)**

Hinshelwood argued that this mode of acquisition is also employed by normal people when they try to learn passages of text, and that if trying to learn a piece of prose by heart, normal individuals will do so more rapidly if they are allowed to read it aloud, than if they are compelled to read it silently. He claimed that the reason for this increased success is that there is simultaneous appeal to three centres: the auditory; speech movements; and the visual.

Hinshelwood's cases five and six had difficulty in acquiring the final stage in reading, which requires reading by sight alone. He claimed that in order to accomplish this proficiently, a very large number of visual memories for words have to be acquired. In this fairly commonly documented disorder, the children show a frequency effect in that short, familiar words are easier to acquire than more rare words. Hinshelwood suggests that these children have been unable:

> unlike the other children to furnish their visual memory centre with the visual memories for words, and it is the great and persevering efforts which are necessary to repair this failure and to remedy this defect which make their educational career so different from that of the ordinary child. (p. 57)

In addition to his cognitive discussion of these congenital disorders, Hinshelwood also made a variety of observations which are relevant to our current conceptions of these disorders. He emphasised that in many cases there is a hereditary aspect to the congenital disorder. The suggestion of congenital word-blindness as a hereditary entity was first proposed by Thomas in 1905. Hinshelwood himself studied six cases of congenital word-blindness spanning two generations and Stephenson (1905) described six cases spanning three generations. Although it is known through current clinical observation that specific reading disorders frequently have familial components, there are still relatively few analyses of reading disorders affecting more than one member of a family and few analyses of the nature of the reading disorders manifest across generations.

Hinshelwood was also aware of methodological issues. He noted (1917) that the incidence of congenital word-blindness would depend upon what the writer meant by the term congenital word-blindness.

> Nothing has been more misleading in medicine than the use of statistics. Figures and percentages are worthless, unless we know precisely the basis on which they have been drawn up. (p. 76)

Hinshelwood considered that the term congenital word-blindness should not be used for every child who experienced difficulty in learning to read, but that there were two important conditions: (1) the defect should be very severe; and (2) the symptoms should be pure. Hinshelwood suggested that where children lag behind others in acquiring reading skills but have a level of deficit which can be overcome relatively easily by remediation, then the term congenital dyslexia should be applied. The term congenital word-blindness should then be reserved for more serious cases of disorder. He suggested that whereas the early descriptions referred to grave cases, the writers who subsequently described cases extended the term to include slight degrees of defect in the visual word centre, rather than the more marked degrees of deficit in the centre which he had described, Hinshelwood also argued that the terms should be restricted to children who have neither generalised intellectual defect nor generalised memory impairment. The specificity of the nature of the memory impairment is emphasised. Hinshelwood is clear that memory for the written word is distinct from other memories. Where the reading difficulty is combined with low intelligence, Hinshelwood proposed the term congenital alexia. He thus distinguished between three different types of disorder, the first two of which would be referred to as developmental dyslexias in contemporary classifications. The distinction between congenital word-blindness and congenital dyslexia is based on the severity of the disorder. The distinction between congenital dyslexia and congenital alexia is based on the other intellectual skills of the child.

TWENTIETH-CENTURY DEBATES

Labelling and Classification

Throughout the rest of the 20th century, there has been continuing discussion and debate regarding both the nature of the labelling of the disorder and the aspects which are most important for diagnosis. This

continues even today with the term developmental dyslexia not being accepted in educational circles and the term specific learning difficulties shifting to 'and from' specific learning disabilities. During the 20th century a variety of other terms have been applied to the condition. Amongst these are strephosymbolia (Orton, 1928), specific dyslexia (Hallgren, 1950), constitutional dyslexia (Skysgaard, 1942), and developmental alexia (Orton, 1937). It was not until 1975, that the medical neurological fraternity formally recognised the condition which Hinshelwood had discussed in such detail, in the earlier part of the century. The World Federation of Neurology defined developmental dyslexia as follows:

> a disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and socio-cultural opportunity. It depended upon fundamental cognitive disabilities which are frequently of constitutional origin. (Critchley, 1970)

This type of definition differs greatly from diagnosis of most medical conditions which will occur on the basis of positive symptomatology. This definition is a definition by exclusion. Dyslexia occurs where there is difficulty learning to read once several things are eliminated: poor teaching; poor intellect; poor socio-economic possibilities. The definition does however recognise the potential constitutional basis of the disorder.

In the 1970s, prevalence statistics were also proposed. Rutter, Tizard, Yule, Graham, and Whitmore's (1976) Isle of Wight study suggested an incidence of 3.5% and the inner London study of Berger, Yule, and Rutter (1975) suggested an incidence of 6%. More recently, Lewis, Hitch, and Walker (1994) tested an unselected sample of children, composed of the population of 9- and 10-year-olds in a single education authority district in England, and found that 6.2% had specific reading difficulties. It remains debated whether these children represent a group who are distinct from the main distribution of children, as suggested by the Isle of Wight study, or represent the lower tail of a normal distribution (e.g. Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992).

Rutter and Newell led the way for a more mathematical definition of the disorder proposing a specific equation in relation to which one could make a formal definition of whether or not a child was dyslexic. The formal equation is documented by Yule, Lansdowne, and Urbanowicz (1982) and is as follows:

$$\textit{Predicted reading accuracy} = -38.86 + 0.63 \times \text{FSIQ} + 0.78 \times \text{Age}$$

This equation is considered appropriate for use in the age range 6–12 years. Tabulated discrepancies between actual and predicted reading scores considered to reach statistical abnormality are of the order of 21 months for significance at a 5% level. In clinical practice, this precise equation is seldom formally applied and a child is often diagnosed as having a specific reading difficulty if the distinction between what might be expected as an appropriate reading level and what is attained is of the order of 2–3 years. Children of high intelligence with reading levels well below their other intellectual skills but nevertheless at an average level for age often fail to be identified as having specific difficulties.

From a cognitive neuropsychological perspective it is not clear that the models or systems which we should use to explain and understand reading disorders must be formally different depending on the degree of impairment in a child's reading. If we are to interpret reading difficulties in relation to a disorder of normal development, or the partial attainment of an adult system, then it ought to be possible to explain all reading disorders, regardless of the severity of the deficit. Similarly, Siegel (1989) has questioned the use of IQ in classifying the developmental dyslexic. The child's intellectual ability may not be relevant in that at all levels the disorders should be explicable in relation to the same model. Yet, in current formulations, it is not possible to describe a child as having a specific difficulty with reading if the child is also intellectually impaired. Children may have a variety of intellectual levels and not have reading difficulties and children with reading difficulties may also have a variety of intellectual levels (Siegel, 1988). We have no documentary evidence that the nature of the reading difficulties manifest in children of limited intellectual ability differ from the nature of the reading difficulties exhibited by the child with specific impairment.

From a cognitive neuropsychological perspective, one would wish to see descriptions of the different types of manifestation of reading disorder in children of normal intelligence and then descriptions of the different manifestations of reading disorder in children of limited intellectual development, in order to determine whether there is anything different in the formal expression of the two groups of conditions. In particular, although group studies have discussed phonological skills in what are called garden variety poor readers (those who are poor at reading and have low IQs) (Stanovich, 1988), there has been no systematic cognitive neuropsychological analysis of individual cases of garden variety reader and there is therefore no evidence about the patterns of reading impairment and their relationships to the pattern of the developmental dyslexias as discussed later.

Biological Bases

Arguments about labelling and classification have unfortunately led to the implication that there is some doubt about whether or not these specific reading disorders exist. However, there is now broadly based biological evidence to support the existence of developmental dyslexia as a specific entity, whatever we may wish to call it. Firstly, it has already been noted, that there is a heredity aspect to some of the conditions and, although the precise mechanism is unclear, familial trends are evident. Vogler, DeFries, and Decker (1985) reported that the risk to a son of having an affected father was 40% and of having an affected mother was 55%, a five- to seven-fold increase in risk over sons with no affected parent. The risk to a daughter of having an affected parent of either sex was 17–18%, a 10–12 fold increase over the risk with no affected parents. In a study of dyslexic twins, Olson, Wise, Conners, and Rack (1989) found significant heritability for a measure of oral non-word reading accuracy. In a minority of families, a linkage between dyslexia and chromosome 15 was reported, with autosomal dominant transmission (Smith, Kimberling, Pennington, & Lubs, 1983). However Pennington (1990) also emphasises that there is genetic heterogeneity in the transmission of dyslexia and no clear convergence on which different modes of transmission are operating. This could account for the failure to find linkage to chromosome 15 in other studies (e.g. Bisgaard, Eiberg, Moller, Niebuhr, & Mohr, 1987). Pennington et al. (1991), in a review of four independent familial samples, concluded that in three a major gene locus was the most likely mechanism of transmission with polygenetic transmission in the fourth.

Secondly, there are the electrophysiological studies, indicating specific EEG abnormalities associated with specific reading difficulties which moreover, indicate that the nature of these abnormalities is not consistent across all subjects but rather, some have more focal abnormalities in temporo-parietal areas and others include a specific frontal focus (Duffy, Denckla, Bartels, & Sandini, 1980; Duffy & McAnulty, 1985).

A series of post-mortem analyses of developmental dyslexics who have died as the result of other illness or accident, has been conducted by Galaburda and colleagues in Boston (Galaburda, 1985; Galaburda & Livingstone, 1993; Galaburda et al., 1985). Although there is some debate about the significance of certain cases for whom there were other neurological complications, there have nevertheless been fairly consistent striking architectonic abnormalities in the majority of the cases that have been investigated, which are not easily explicable. These have taken the form of foci of ectopic neurons and focal microgyria constellated particularly in areas of the left hemisphere with minor representation in the right hemisphere. The locations of these abnormalities within the left hemisphere have been fairly broadly distributed but have included those centres which we would classically consider to be involved in language and reading: the perisylvian cortex, inferior frontal cortex, the parietal operculum, parietal lobe, and temporal gyri (Galaburda, 1994).

The basis for the abnormalities is unknown and, although the Geschwind and Galaburda (1985) theory has remained controversial in suggesting that the abnormalities result from hormonal anomalies during foetal development, the basic post-mortem results nevertheless remain striking, One difficulty in interpreting these cases is the limitation in the number of comparable detailed analyses of non-dyslexic subjects, the time scale and effort required to conduct such analyses providing part of the explanation for limitation in studies. The specificity of the abnormalities is also unclear as abnormalities of cell migration have also been postulated to be associated with a broad range of other developmental disorders.

MRI studies have reported increased symmetry of the planum temporale in subjects with dyslexia (Hynd, Semrud-Clikeman, Lorys, Norey, & Epiopulos, 1990; Larsen, Hien, Lundberg, & Odegaard, 1990) and symmetry in the superior surface of the temporal lobe (Kushch et al., 1993). A higher incidence of bilateral anomalies is also reported (Leonard et al., 1993). Studies reporting differences in the size of the corpus callosum between dyslexics and controls have been contradictory (Duara et al., 1991; Hynd et al., 1995; Larsen, Hoien, & Odegaard, 1992). PET studies have demonstrated abnormalities in cerebral blood flow in the left temporal parietal region in men with dyslexia when carrying out a rhyming task, with normal patterns of activation on non-linguistic tasks, and normal activation of fronto-temporal cortex during syntactic processing (Hagram et al., 1992; Rumsey et al., 1992, 1994). This argues for a left hemisphere dysfunction restricted to posterior language areas. Flowers, Wood, and Naylor (1991) report that when poor readers carry out a spelling task, which in normals activates classical Wernicke areas, the area in the immediately posterior temporo-parietal region is activated instead.

A further argument for a biological basis to developmental dyslexic disorders is the evident sex difference in incidence and, although precise proportions are unclear, the ratio of males to females with dyslexia is of the order of 2 or **3:1**. In the recent study of Lewis et al. (1994) a ratio of 3.2:1 is reported.

It has also repeatedly been argued that the incidence of left-handedness is higher amongst people with specific reading difficulties. However, this supposition has been the focus of considerable recent

dispute and Bishop (1990) has argued that such a view cannot now be substantiated. Nevertheless, in combination, the biological evidence from genetic, electrophysiological, and post-mortem studies supports the view of developmental dyslexia as a congenital neuropsychological disorder.

Unitary Factors

The principal research efforts addressed at the developmental dyslexias in the 1960s and 1970s concerned group studies with a quest for a unitary associated factor that might be causal in generating the disorders. However, there is a limitation to the amount of information that may be obtained within group studies if the group involved is not homogeneous with respect to the factor under investigation. Despite Hinshelwood's (1917) early documentation of the different formats of developmental reading disorders, the multiple syndrome nature of developmental dyslexia continues to be ignored in many studies. Some of the early attempts to categorise the developmental dyslexias described a variety of syndrome features which were believed to co-occur in particular dyslexic populations. A number of these features did not relate to the reading process itself. However, with increasing investigation of the disorders it has been difficult to substantiate these different syndrome groupings. While certain symptoms co-occur in some children, in other children they fractionate and dissociate, indicating that they are not intrinsically interrelated.

Contemporary psycholinguistic analyses of the developmental dyslexias adopt a methodology comparable to that which has been used with the acquired dyslexias. They echo aspects of the analyses conducted by Hinshelwood (1917) but with more systematic decomposition of the precise nature of the response evoked by the presentation of particular types of linguistic material. Before presenting specific case descriptions of these disorders some models should be proposed. The case reports will then be discussed in relation to these formulations.

MODELS OF NORMAL READING

Stage Models of Normal Reading

Within the neuropsychological literature there continues to be discussion of the stage models of Marsh et al. (1981) and Frith (1985). The stages in these models of acquisition are summarised in Table 5.1. The Marsh et al. (1981) model postulates four stages in reading acquisition. The first stage is referred to as *glance and guess*. In this stage of reading development, children are able to recognise a small set of words by sight. They have no phonic skills. They are unable to read unfamiliar words except by guessing within a story. The word guessed does not in any systematic fashion resemble the target word. If in reading the sentence *the boy went to the moon in a rocket,* the child guessed "spaceship" for rocket, this is a guess based on general context rather than the extraction of partial information from the word spaceship. A similar guess would have been proposed even if the written sentence had been *the boy went to the moon in a cauliflower.* Thus, meaning related guesses take place only in the context of the story and are not the true semantic errors of the acquired neurological literature.

Stage two in the Marsh model involves the acquisition of more *discrimination net guessing.* Normally, within the first year of reading acquisition there will be progress to this stage. Stage two begins the building up of sight vocabulary. Now when words which are unfamiliar are guessed at in context, known words are used to constrain the guesses. The children also look for overlap between the stored visual units and the new words. Thus the guesses now begin to resemble the target visually. At this stage, aspects of approximate visual access are employed.

In stage three, there is acquisition of *sequential decoding* with simple grapheme to phoneme correspondences. The child is taught or notices that certain letter groups are pronounced in the same way in different words and that it is therefore possible to work out a new word's pronunciation. Decoding is initially a simple left to right sequential process. Subsequently, digraphs and specific rules are mastered. The reader becomes more versatile. In stage four, skilled reading has been acquired, which is context sensitive and also incorporates aspects of reading by analogy. It involves *hierarchical decoding.* This stage is typically not reached until the middle years of childhood.

Marsh's model (Marsh et al. 1981) was modified by Frith (1985) who delineated a three phase rather than a four phase theory. Each phase follows the other in sequential order and capitalises upon the previous one. In the first *logographic phase* a sight vocabulary of instantly recognisable words is built up. Phonological factors are secondary, i.e.

TABLE 5.1
Proposed Stages of Normal Reading Development

Marsh et al. (1981)	*Frith* ***(1985)***	***Ehri (1991, 1992)***
1. Glance and Guess	**1.** Logographic	1. Logographic
2. Discrimination Net Guessing	**2.** Alphabetic	**2.** Phonetic Cue
3. Sequential Decoding	**3.** Orthographic	**3.** Cipher
4. Hierarchical Decoding		

the child only pronounces the word after if is recognised. In the second *alphabetic phase* the analytical skill of decoding graphemes to phonemes in sequential order develops. In the final *orthographic phase* words are systematically analysed into orthographic units (ideally morphemes) without phonological conversion. These units are internally represented as abstract letter-by-letter strings.

Frith (1985) argued that the early logographic skills might lead to the formation of input logogens (Morton & Patterson, 1980) or word form analysers (Shallice & Warrington, 1980). Alphabetic skills might lead to the development of grapheme to phoneme conversion systems (Coltheart, 1978). Orthographic skill acquisition leads to word component analysers (Shallice & McCarthy, 1985; Shallice, Warrington, & McCarthy, 1983; Temple, 1985b). Thus, this model predicts a sequential basis to the acquisition of components of a normal adult reading system, a model of which will be discussed later. Morton (1989) also incorporates a single, universally applicable programme of stages in literacy development to attain the adult system. Seymour and MacGregor (1984) retain the three stages proposed by Frith (1985) but develop them within a model **of** the reading system in which there are two distinct lexicons. The logographic reader sets up a logographic lexicon; the orthographic lexicon develops out of an alphabetic lexicon. Once established, both lexicons remain throughout life. Later Seymour modified this view of the relationship between the alphabetic and orthographic lexicon (see the later section on hyperlexia).

A fundamental principle of these stage theories is that all children pass through the same stages in the same invariant order. In contrast, Stuart and Coltheart (1988) argue that there are individual differences in the patterns of acquisition. They report that children who are phonologically skilled use phonological skills from the beginning and do not go through a logographic stage. Ehri (1987) also argues that although pre-readers may use visual or context cues to identify words, as soon as children move into reading they shift to letter-sound cues. Wimmer and Hummer (1990) report that alphabetic strategies are also used from the beginning in German children who are learning a language which is phonologically transparent. However, they argue that this gives the German children an advantage in reading nonsense words over English children for whom such a strategy is less common (Wimmer & Goswami, 1994).

Stuart and Coltheart (1988) do not argue that all children use phonological skills from the beginning. Children who are not phonologically skilled may initially treat reading as a visual memory task, and may become logographic readers. In Stuart and Coltheart's view, children use whatever skills they have available when learning new words, and the available skills differ between children.

Multiple Route Models of Reading

In the late 1970s and through the 1980s, a series of different dual or triple route models of normal adult reading were proposed. They incorporated a variety of similar principles but there are slight variations in the features incorporated from one research group to another. I will discuss my own formulation here (Temple, 1985c) but this derives in large part from previous work (Coltheart, 1978; Morton, 1969, 1979; Newcombe & Marshall, 1981; Shallice et al., 1983). Further, although the case reports presented later will be discussed in relation to this model, they could easily be discussed in relation to other similar formulations and a discussion of this sort is not dependent upon the acceptance of the precise features of the specific formulation presented here.

In the late 1980s and early 1990s, parallel distributed processing models and other network models have become popular in discussions of the underpinnings of cognitive systems. Some argue that these should supplant the modular information processing models. Others argue that they merely depict mechanisms to represent the acquisition of information within the modules of previous models. Whichever stance is valid, and these models will be discussed further later, a detailed understanding of the multiple route models of reading and their implications clarifies the developmental thrust of the field, some of the focal theoretical issues, and outlines the psycholinguistic distinctions of relevance to a developmental cognitive neuropsychology of literacy.

The early dual route models (see Fig. 5.1) indicated two routes by which a word might be read aloud. When reading occurs via route 1, the *semantic route*, the following stages occur. Following preliminary visual analysis, abstract letter representations are extracted. The system which is involved in determining these aspects is not sensitive to whether the letters are lower case, upper case, or hand written. The result of this process feeds into a system of representation which in Morton's models are referred to as *input logogens*. In Shallice et al.'s (1983) formulations the system is referred to as a *visual word form system*. In my own model, the system contains *word detectors*. The system contains representations of words which are activated by visual input. The words have thresholds of activation, such that a word of higher frequency is more easily activated than a word of low frequency, since words of high frequency have lower thresholds. There is a biological analogy employed in this recognition system, which is similar to the activation of neuronal responses. Evidence is summated and if it reaches the critical threshold the word detection is activated. Thus, the

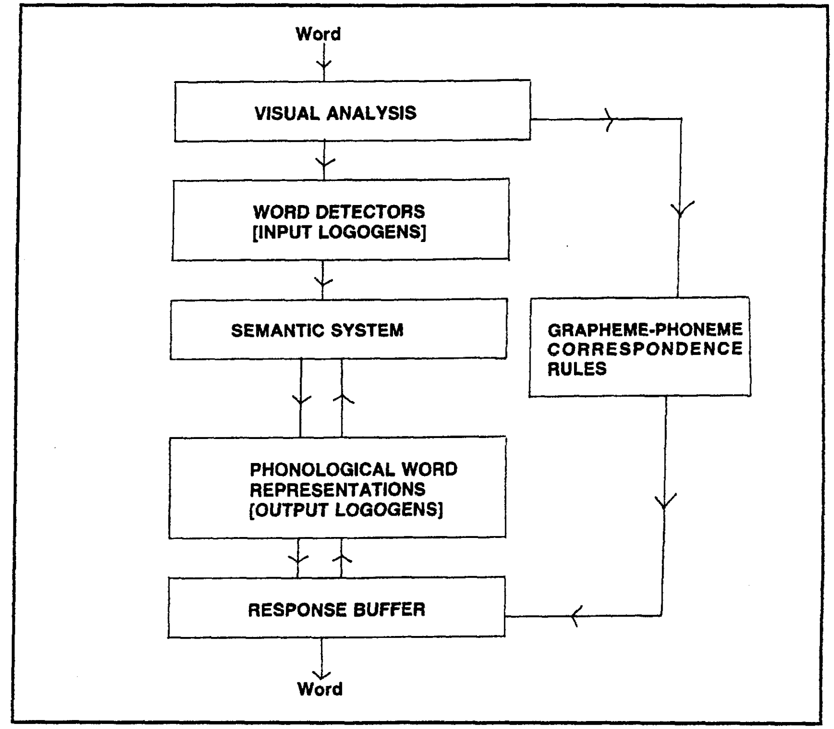

FIG. 5.1 A dual route model of reading.

triggering or not of an item within the store resembles the all-or-none firing of classical descriptions of neuronal transmission. (Such classical views of neural transmission no longer remain valid (Temple, 1993).

The word detection system contains stores of words based upon morphemic representations. Thus, the word *tree* and the word *trees* activate a similar morpheme tree within the system. The processing of affixes, or other bound morphemes, is represented differentially across models and will be discussed further later. Subsequent to activation of the logogen, a representation is triggered within the *semantic system* which provides information about the meaning of the word and its associations. This meaning then activates a representation which is phonologically based and which is referred to as an *output logogen* in Morton's model, and a phonological representation in other models. This pronunciation can either be spoken aloud or can be held in a *response buffer*. The crucial element of dual route models is that the systems employing whole word recognition via the semantic system are distinct from the *phonological reading route* which is marked as route 2 in Fig. 5.1.

The phonological reading route involves a system within which following visual analysis, words are broken down into components. These are then associated via a system of rules with the words' pronunciation. The initial formulations of this rule system were based upon grapheme to phoneme rules (e.g. Coltheart, 1978). Subsequent models suggested that the orthographic unit upon which the conversion rules were based may be variable in size. Shallice and colleagues (Shallice & McCarthy, 1985; Shallice & Warrington, 1980; Shallice et al., 1983) suggested that correspondences could be based upon larger orthographic segments and suggested that there were translation rules for graphemes, consonant clusters, sub-syllabic units, syllables and morphemes. They postulated a visual word form system, composed of orthographic units for letter groups, which exist in at least one English word to which the subject has been exposed. Such units might be restricted to letter groups with functional phonological or semantic correspondence. The orthographic units would activate corresponding units in a phonological system. Orthographic units with more than one possible pronunciation would have the distinct pronunciations represented by separate correspondence rules, differing in strength. This system which links the word form system to a phonological data base is labelled by Shallice and McCarthy (1985) as "phonological correspondence processing'' (p. 364).

The ambiguity and disagreement in the precise way in which such a system should operate is reflected in the model that adorns the cover **of** Patterson, Marshall, and Coltheart (1985) (see Fig. 5.2). Here the phonological reading route becomes described ambiguously as a system of "orthography to phonology (sub-word level)". Its point of exit and entry in relation to other reading routes is sufficiently uncertain to warrant representation by a dotted line. The model adorning the cover of this book also depicts a third reading route labelled as orthography to phonology (word-level). The third route is generally referred to as the direct reading route. In a more simply depicted triple route model **of** reading (see Fig. 5.3) the direct route passes directly from input logogens to output logogens or from word detectors to phonological word representations.

The direct route was introduced into reading models following the description by Schwartz, Saffran, and Marin (1980) of a dementing patient who remained able to read irregular words aloud correctly, at a point when comprehension of their meaning had been lost. Irregular words do not conform to spelling to sound pronunciation rules and therefore cannot be read aloud correctly by the phonological route. Such

words had previously therefore been believed to be read by the semantic reading route (route 1 as depicted on Fig. 5.1 and Fig. 5.3). However, reading via the semantic reading route involves activation of the meaning of a word prior to its pronunciation. For the patient described by Schwartz et al. (1980) this meaning was not accessible as a result of the deterioration associated with the dementia. The patient was therefore described as having direct dyslexia, in which direct access from word detectors to phonological representations bypasses semantics. This form of dyslexia is relatively common in patients with dementia of Alzheimer's type. The reading disorder is not consistent in its format throughout the process of deterioration but is evident at a particular stage and has been further explored by Hodges et al. (1992). As the cover picture of Patterson et al. (1985) illustrates (Fig. 5.2) the relationship of the direct reading route to the phonological reading route is vague. In Shallice and Warrington's formulations (e.g. Shallice et al., 1983) the

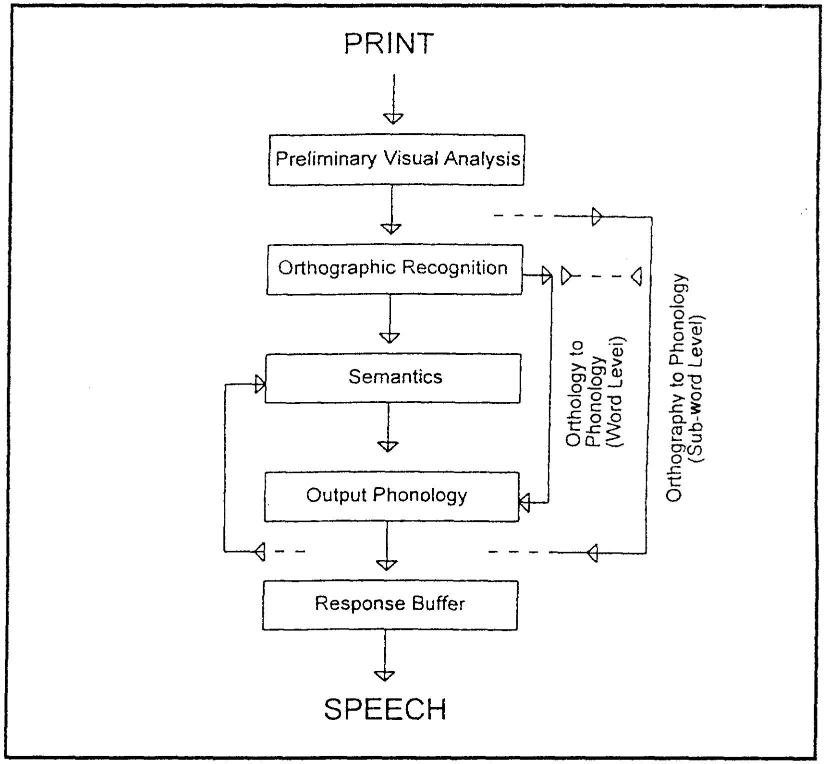

FIG. 5.2 Patterson et al.'s (1985) model of reading.

direct reading route is abandoned altogether in favour of the expanded phonological route. Temple's (1985c) formulation retains all three routes.

Temple (1985c) makes the relationship between the alternative reading systems more explicit (see Fig. 5.4). A further modification to the early depiction of the phonological reading route is also represented. Prior to the rule based translator a *parser* is activated in segmenting the words into chunks. A chunk is defined as the written representation of p phonemes where $0 < p < n$, and n is the number of phonemes in a word. The preferred parsing depends upon the experience of the reader. Treiman (1992, 1993) provides evidence that children must use multi-letter units within any phonological translation system. The *translator* also contains representations of more than one translation possibility. Thus, a chunk like *ead* would have available a translation rule parallel to that in *dead* and that in in *bead*. More translation rules are internalised as contact with the written word increases. Although in

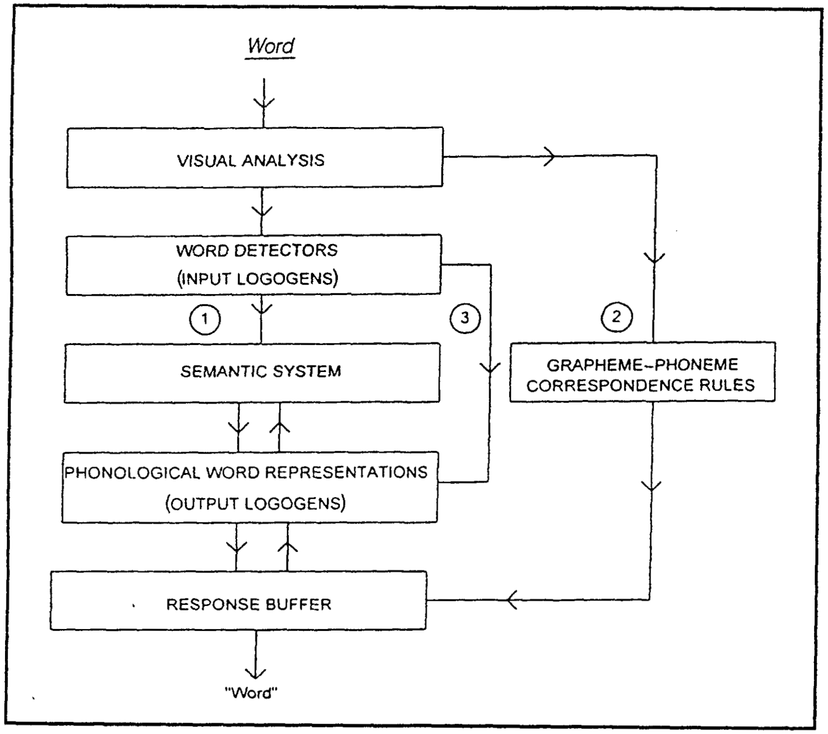

FIG. 5.3 Triple route model of reading: 1. The semantic route; 2. The phonological route; 3. The direct route.

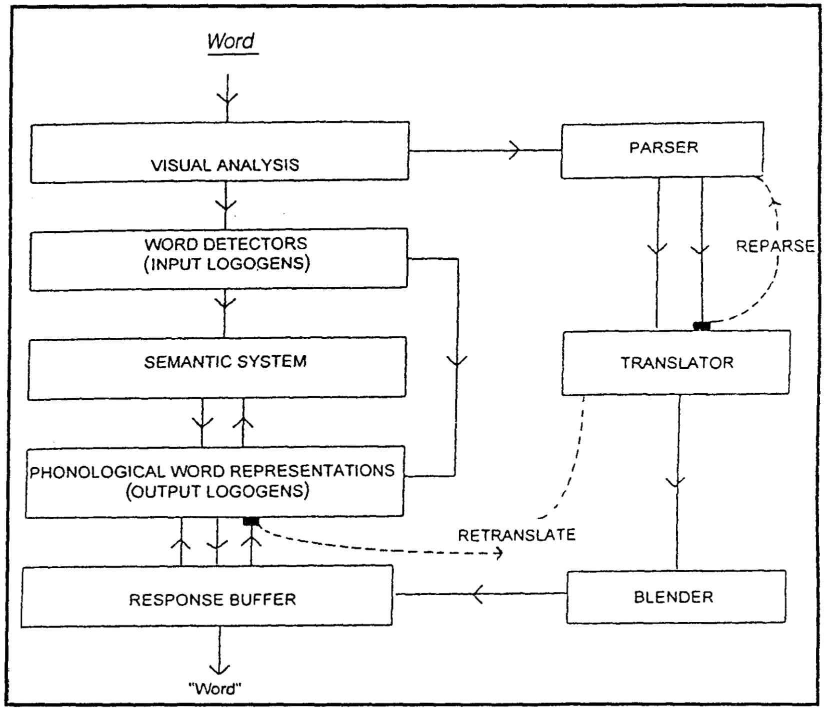

Fig. 5.4 Temple's (1985c) model of reading.

Temple's (1985c) formulation it was proposed that young beginning readers parse into smaller chunks than experienced readers, more recent studies suggest that in some normal children the reverse pattern operates, i.e. children parse words into larger chunks prior to attending to smaller chunks (e.g. Goswami & Bryant, 1990). The issue of the development of the parser therefore remains open. Acquired surface dyslexia may be explained as a malfunction of the parser, in which parsing operates on chunks below the optimum level. Acquired phonological dyslexia may result from a malfunction of the parser in which parsing operates on chunks above the optimum level. These interpretations will be discussed in more detail below in relation to developmental abnormalities. Normal young children, may also sometimes parse into chunks which are non-optimal, if their experience with the written word has not yet been sufficient to internalise more substantive parsing rules. In such cases, their reading performance may resemble surface dyslexia, a comparison first noted by Marcel (1980). Though as Seymour (1986) notes, even when patterns of performance are similar, dyslexics and normals may be differentiated by their speed of response.

Subsequent to the translator, Temple (1985c) depicts a *blender*, which combines phonological segments and produces an integrated phonological output. Malfunctions of the blender produce emissions or repetitions of phonological segments in the overt responses. The translator itself is capable of rejecting an input. If it has no representation of any chunk resultant from prior parsing, it may trigger a re-parse operation. Thus, Temple's model incorporates feedback routes. Once the translator has accepted an input it selects between valid alternative translations by attempting that of higher token frequency first. If this ultimately produces a neologistic response, a mismatch with known words is detected and a retranslation will occur. This system is frequently under conscious control and may prevent the production of neologistic responses. The translator may malfunction by mismatching orthographic and phonological chunks. As discussed later, surface dyslexia may be used to investigate malfunctions at different levels of this system.

Connectionist Models

An alternative to the multiple route models is the single route analogy model (Glushko, 1979). In this model, there is a single procedure which is used to read aloud both non-words and irregular words. The model in its initial formulation was difficult to test but it was then incorporated into an explicit connectionist model by Seidenberg and McClelland (1989). In this model, a set of hidden units connects an orthographic store, which codes the visual properties of words, and *a* phonological store, which codes their phonological properties. The connection weights, via the hidden units between the two stores, are established by training using the back propagation algorithm of Rumelhart, Hinton, and Williams (1986). The model establishes correspondences between English words and their pronunciations, which are stores in the connection weights. Regularity effects emerge as a consequence of the probabilities of exposure to particular types of word. The network was also able to "pronounce" non-words on which it had not been directly trained.

There were however, a number of criticisms of the model. One problem related to non-word reading. For example, Besner, Twilley, McCann, and Seergobin (1990) showed that the network was much poorer than normal adults at both reading aloud non-words and at lexical decision. Coltheart and Leahy (1992) demonstrated that young children also read non-words with better accuracy than the model predicts. The model also had difficulty in accounting for the range of patterns of acquired dyslexia

which may follow brain injury. In particular it was unable to offer an account of the double dissociations evident within the acquired dyslexias (Castles & Coltheart, 1993), and for cases where non-word reading may be better than word reading (Coltheart, Curtis, Atkins, & Haller, 1993). This limitation is also relevant for the cases of developmental dyslexia which will be discussed below.

More recently, in response both to the difficulties in accounting for the patterns of the acquired dyslexias and the skill of normal subjects in reading non-words, revised connectionist models have been proposed which are better at reading non-words and which incorporate dual routes (Plaut & McClelland, 1993; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg, Plaut, Peterson, McClelland, & McCrae, 1994). Thus, connectionist models have become multiple route models.

One of the distinctions between connectionist and some non-connectionist models of normal reading now lies in the number of routes involved. Both types of model have a semantic reading route. However, the connectionist models have a route which incorporates elements of both the phonological and direct reading routes of triple route models, whereas triple route models retain a distinction between the two. Note however, that the non-connectionist model of Shallice et al. (1933) also incorporates the phonological route into the direct route. Thus, for many theorists the two groups of models have become close. Nevertheless, Besner (in press) argues that the three route model continues to provide a better account of the data, and there remains some degree of division between the McClelland/Seidenberg/Plaut view and the Coltheart/Besner view, albeit with considerable overlap between the two previously opposed perspectives.

Recent PET studies also support the multiple route hypotheses. For example, Bookheimer, Zeffiro, Blaxton, Gaillard, and Theodore (1995) report activation of an inferior temporal pathway in silent reading and object naming where there may be direct access to a lexical entry. In reading aloud there is activation of a superior temporal-inferior parietal route which may involve the sequential transcription of visual elements into phonological sounds.

Developmental Connectionist Models

Both Ehri (1980,1984, 1991,1992) and Perfetti (1992) have attempted to incorporate analogy theory and the older version Seidenberg and McClelland (1989) model into a developmental model, Ehri argues that in order to establish a sight vocabulary (the lexical or semantic route[s] of multiple route models) phonological recoding is required. Ehri believes that phonological recoding is a prerequisite for learning to read and that dual route models do not explain this. Over time, as a word is established in sight vocabulary, the need for phonological recoding is eliminated. In Ehri's model the use of phonological recoding leads to the establishment of a visual-phonological route. Spelling units become linked to pronunciation units. Readers find words in lexical memory via connections linking spelling to pronunciation, rather than links between spelling and meaning, although connections between spelling and meaning are also formed. However, the access to pronunciation is not like that in the phonological reading route. Access to lexical memory to locate pronunciation is not via grapheme–phoneme conversion rules but via the word's spelling. In Ehri's theory, letters in spelling symbolise the phonemes used to pronounce words leading to the visual–phonological connection. Spelling and pronunciation are therefore merged in visual–letter analysed representations. These representations are then amalgamated to meanings and this amalgam is activated in sight reading, via the visual–phonological connection.

Ehri goes on to incorporate these ideas into a stage model. In the logographic phase rote memory is used to link visual cues and word meaning as there is no letter–sound system knowledge. In a phonetic cue reading phase, readers use a basic knowledge of letter names or sounds to form partial connections between spelling and pronunciations. Finally, in the cipher phase, phonological segmentation and recoding skill enables the formation of complete connections between the entire spelling of the word in memory and the phonemic units in its pronunciation.

Perfetti (1992) proposes a restricted interaction model of reading within which there is interaction of information within the lexicon and reciprocal activation between letters, words and phonemes, as well as multiple letter and multiple phoneme units. At the same time, there is restriction on the influence of information from outside the lexicon. In particular, general knowledge and expectancies have little or no influence on the initial access of a word, so that the lexicon is itself autonomous or modular. Perfetti (1992) claims to be merging the interactive principles of McClelland and Rumelhart (1981) and the autonomous principle of Foster (1979). In the Perfetti (1992) model, phonemic activation occurs as an intrinsic part of lexical access. There is also a single representation which serves both reading and spelling.

In the acquisition of this system, rules have a minor role and the major development is in the acquisition of individual word representations which as skill develops increase in number and quantity. Within the lexicon, there are two subsections. The beginning reader develops a functional lexicon which is not autonomous and has contributions from knowledge, expectations, and context. The representations within this are under-specified. A second autonomous lexicon is also established which has fully specified and redundant representations. Specific words change status to join this lexicon. Speed of correct spelling is taken as an index of a representation within the autonomous lexicon. Although computational phonemic knowledge is required to develop the functional lexicon, the explicit reflective phonemic knowledge required by most tests of phonemic awareness, such as rhyming and phoneme deletion, develops through experience with alphabetic stimuli.

In this model speech codes are part of the lexical representation. Thus phonemic information is activated during lexical access. There are qualitatively no differences in the representations of words, and regularity and irregularity have no bearing on representation. The stronger the context-sensitive rules, the more entries a learner can acquire. The more entries, the more powerful the decoding rules, Lexical learning is therefore highly interactive. Perfetti argues that he finds the existence of Boder's (1973) dyseidetic dyslexics who use only a visual strategy unconvincing. There appears to be a confusion over terminology here, since Boder's dyseidetics are children who have both surface dyslexia (see later) and surface dysgraphia (see Chapter 6). Such children use phonological not visual strategies, which Perfetti could accept. Non-phonemic spelling strategies are a feature of phonological dysgraphia (see Chapter 6) and Boder's dysphonetic dyslexics. Perfetti's model (1992) has difficulty in accounting for the patterns of the developmental dyslexias, just as the earlier connectionist models did in accounting for the acquired dyslexias (see later discussion).

We turn finally to the cognitive neuropsychological analyses of the developmental dyslexias and their theoretical interpretations. In historical terms, developmental surface dyslexia (Holmes, 1973) was described before developmental phonological dyslexia (Temple & Marshall, 1983). It will therefore be discussed first amongst the dyslexic disorders.

DEVELOPMENTAL SURFACE DYSLEXIA

The suggestion that a pattern of reading performance which has been labelled developmental surface dyslexia might be found amongst developmental dyslexias was first proposed by Holmes (1973) in her doctoral thesis and by Coltheart, Masterson, Byng, Prior, and Riddoch (1983) who described the case of an 18-year-old girl CD, of average intelligence but with a reading age of 10 years. CD displayed a significant regularity effect in reading words aloud, in that words that conformed to spelling to sound rules were read more easily than those which were not consistent with such rules. Her errors showed the application of a rule based system, e.g. *bear*→“beer”; *subtle*→“subtill”. She also displayed homophone confusion, in that words with the same pronunciations but different spellings were confused. For example, she defined *pane* as “something which hurts”. Prior to the discussion of the features of developmental surface dyslexia in relation to models proposed earlier, a case description will be presented upon which to base the discussion.

Case Report: Developmental Surface Dyslexia, RB

RB was first described at the age of 10 years (Temple, 1984b, 1986b). Further aspects of her performance are expanded upon here. There were no features of concern during pregnancy or the early months of life. Early motor milestones and language development were satisfactory with plentiful, clear speech well before the third year. There were no early illnesses nor injury of any significance. Concern at slowness in learning to read started around age seven.

On examination by a paediatric neurologist, RB was reported as an alert, cooperative, attentive child of good intelligence. Skull, spine, stance, gait, visual acuity, and hearing were all within normal limits. There was minor dyspraxia apparent in ocular motor movements and sequential finger movements with slight impairment of imitative movement but overall RB was presented as a healthy child whose development appeared normal. The report concluded that there was “no evidence of neurological defect”. There was a family history of literacy difficulties.

At the age of 10, the Wechsler Intelligence Scale for Children was given to RB. A full scale IQ of 115 was obtained. The following subtest scores were attained:

Verbal Tests		*Performance Tests*	
Information	11	Picture Completion	10
Similarities	12	Picture Arrangement	12
Digit Span	14	Block Design	12
Vocabulary	17	Coding	8
Verbal IQ	122	Performance IQ	104

(mean subtest score = 10; range 1-19; SD = 3)

On the Peabody Picture Vocabulary Test, RB attained a raw score at the 99th percentile for age. These tests indicated that RB was of at least average intelligence with an extensive vocabulary. At the time of assessment RB was 10;10 and had a reading age for accuracy on the Neale Analysis of Reading of *8;7*. The progress of her reading and change over time is discussed later.

Non-word Reading. Three lists were presented to RB. On each list, half the stimuli were words and half were matched to pronounceable non-words made from the words by altering one letter. The first list contained stimuli three letters in length, and the second contained stimuli five to six letters in length. The third list consisted of the shortest stimuli taken from an unpublished list of Coltheart’s, normally used as a lexical decision task. On these lists RB read respectively, 13 words and 12 non-words; 12 words and 11 non-words; and 23 words and 20 non-words. There was no significant difference between her performance in reading words and in reading non-words. Thus, she displayed one of the fundamental characteristics of surface dyslexia, in that non-word reading is as good as word reading. In Castles and Coltheart’s 1996 study of the surface dyslexic MI, it was also emphasised that in surface dyslexia, non-word reading is at age level and unimpaired in relation to peers.

RB was also presented with Temple’s homophonic non-word list (Temple & Marshall, 1983). Of her errors, 11 were to stimuli homophonic with real words and 10 to stimuli non-homophonic with real words. For RB, being a homophone with a real word was not a determinant of whether a non-word would be read more easily. Her ability to read aloud non-words was independent of whether the pronunciation is identical to a real word. There was thus no evidence of any interaction with established lexical stores.

Reading Words Aloud. RB’s reading analysis was based on her reading of 434 words, 181 of which she read correctly. 64% of errors were neologisms and 36% were paralexias. Of the neologistic error responses, 36% were valid, in that they conformed to the application of a rule based pronunciation system, e.g. *anchor*→“/æntʃɔ/”; *dumb*→“/dʌmb/”.

These two examples are classic regularisation errors. There are other valid errors which are not classic regularisations but which do conform to the application of a rule based system if lower frequency correspondences are permitted, e.g., *break*→“/brɛk/”; *host*→“/hɒst/”; *teach*→“/tiætʃ/”. Although there were fewer paralexic responses than neologistic responses, a number of the paralexic errors are also valid, e.g. *baker*→“backer”; *aide*→“eyed”; *sweat*→“sweet”; *sour*→“sore”.

The majority of paralexic errors (75%) were visual paralexias where the response shared at least 50% of the letters in common with the stimulus, or vice versa. However, since paralexic errors were very much less frequent than the neologistic errors, these visual paralexias represent only 24% of the total error responses. Examples of the visual paralexic errors are *orchestra*→“orchard”; *mattress*→“matters”; *metal*→“mental”; *steak*→“shark”.

Only 1% of RB’s errors could be classified as morphological paralexias, in which the base of the word is read correctly but an affix is dropped, added, or substituted. As will be discussed later, this error type is very common in developmental phonological dyslexia but is virtually absent from the error corpus of a relatively pure surface dyslexic. Within the error corpus of RB there were also no errors of the pseudo-derivational type which will be discussed later in the section on developmental phonological dyslexia.

In addition to these general error types, RB was also somewhat unusual as a developmental dyslexic of this age, in persisting in showing letter orientation confusions, particularly u–n confusion. Thus, for example, she made the errors, *soul* →"/sʌnl/"; and *doubt* →"/dʌnt/". This feature of performance is not known to be characteristic of other surface dyslexics.

Regularity Effects. RB was presented with 78 words on the Coltheart, Besner, Jonasson, and Davelaar (1979) list. Half these words are regular and half irregular; they are matched for frequency, number of letters, number of syllables, and part of speech, but not for imageability. RB read 24 regular words correctly but only 10 irregular words. Whereas such regularity effects are also seen in normal children learning to read, in surface dyslexia they persist beyond the normal age at which they would reduce in evidence.

Investigations involving the presentation of matched lists which explored effects of frequency, imageability, length, and word class were all non-significant with RB. The only linguistic dimension which clearly affected reading performance was spelling to sound regularity, with irregular words being read more poorly.

Homophone Reading. 40 words on Temple's homophonic word list (Temple, 1984c) were presented in random order for reading aloud. The homophonic stimuli on this list are all regular. After reading each word, RB was asked to define it. Of the 21 words read correctly, 10 appropriate definitions were given and homophonic definitions. Examples of these responses are as follows:

male: "chain mail or mail in the mornings"
dye: "kill yourself"
heel: "cut my knee and it heals"
steal: "a kind of metal"
peace: "a piece of paper"

Thus, when RB read a homophone correctly, her ability to assign meaning to it was random with respect to the word itself and its homophones. Meaning was derived not directly from the appearance of the word but indirectly from its phonological recoding.

Typescript Distortions. In four different test sessions RB was presented with 25 words written in one of four formats: normal typescript, handwriting, reversed lower case typescript, and reversed upper case typescript. Her performance is summarised in Table 5.2.

Reversing the order of the letters in the words did not impair performance. For RB distortions of the global characteristics of words did not impair the ability to read them if the individual letters remained distinguishable.

Theoretical Explanations. RB's pattern of reading performance may be explained in relation to the Marsh et al. (1981) model of reading development as an arrestment of acquisition which has produced a pattern of reading performance characteristic of stage three of reading acquisition, sequential decoding, but which has failed to progress to stage four, hierarchical decoding. RB had mastered some simple grapheme–phoneme correspondences and was able to implement these in a simple right to left fashion but she had not been able to become a versatile, skilled reader with context sensitivity, analogical reading, and whole word recognition.

Similarly, in relation to Frith's (1985) model of reading development, developmental surface dyslexia can receive a relatively straightforward explanation in relation to arrestment at the second stage, the alphabetic stage of reading development. There is mastery of grapheme to phoneme rules and some other correspondence rules but there is a failure to proceed to the sophisticated, orthographic reading that characterises normal adult reading performance. This has particular impact in a language like English in which there are a large number of irregular words and appropriate orthographic reading is required for effective reading of the language. In a language such as Italian or Spanish where the correspondence rules are significantly more regularly invoked, a child with developmental surface dyslexia would be significantly less impaired. In these languages, mastery of alphabetic routes may be sufficient to provide the child with a code to decipher words. This may be slower in its application than instant recognition of the word, but should nevertheless be effective in enabling activation of the pronunciation and thereby the meaning of the word.

TABLE 5.2
Reading of Distorted Typescript by a Surface Dyslexic

Stimuli	***Example***	*Number correct*
Normal typescript	e.g. large	10/25
Handwritten		6/25
Reversed lower case	e.g. egral	12/25
Reversed upper case	e.g. EGRAL	13/25

It was noted above that there is some debate about whether the series of stages, as outlined by Frith (1985) are followed for all children. In particular, it was noted that some children appear to start with an alphabetic stage. In such interpretations, RB would be arrested at this initial phase of reading. If it is accepted that there are different routes to reading acquisition then RB is placing greater emphasis upon alphabetic strategies (Stuart & Coltheart, 1988).

Just as acquired surface dyslexia may be interpreted in terms of an impairment of semantic route reading and direct route reading, with preservation of phonological route reading, so RB the developmental surface dyslexic may be interpreted in a similar fashion. It can be argued that the direct and semantic reading routes have failed to become established properly, and that there is therefore over-reliance upon phonological reading. This explanation can account for the main characteristics of the disorder. The good reading of non-words in relation to words results from good development of phonological reading route mechanisms, which enable, by the application of a system of rules, the pronunciation of unfamiliar stimuli. The presence of a marked regularity effect can be explained in a similar fashion. The over-reliance placed on phonological reading means that this route is used to read and pronounce a number of irregular words that would normally be dependent upon semantic or direct route reading for their word-specific pronunciation to be activated. The application of a logical system to these irregular stimuli produces errors, and in many cases these errors are regularisation or valid errors as illustrated earlier. In RB's case, the presence of a large number of neologistic errors further confirmed that reading is not resulting from the activation of phonological representations of words, stored in relation to the whole word. It is also evident that the feedback mechanism which would normally prohibit the activation of these neologistic responses in Temple's model (see Fig. 5.4) is not effective in RB's case.

Homophone confusions can be seen to arise because meaning is being activated after the activation of pronunciation. The semantic representations associated with lexical entries, in Fig. 5.4 are triggered after the phonological representation for the word by feedback up the lexical route. The representation that activates semantics therefore has no information about the original visual representation of the word, and the child is unable to distinguish between alternative meanings associated with identical pronunciations.

This analytical reading system, upon which the surface dyslexic depends, is not itself dependent on the overall visual characteristics of the word. It therefore works as effectively when the words are written

in the normal direction as when the letters are written in the reverse order. RB's performance is unaffected by such reverse type distortions. When the distortion applied to the typescript is sufficient to reduce the clarity of individual letters, the performance declines. Thus, handwritten text is more problematic, since the individual letters and graphemes to which the translation rules are to be applied may be difficult to abstract. RB is not able to use the overall visual characteristics of the word to activate word recognition units, a mechanism which could function relatively effectively independent of specific information about each and every constituent letter.

If RB is to be interpreted as a child who reflects an impairment in the acquisition of semantic and direct reading systems, but with relative preservation of phonological reading routes, she does not represent an absolute dissociation. If her phonological reading route was perfectly established there should be no examples of errors that are not entirely valid. Thus, for RB we must also postulate some impairment within the phonological reading route itself.

Suggestion of impairment at the level of the parser is evident in the translation of some digraphs, with the assignment of a pronunciation to each of the component letters within the digraph. For example, the word ashamed is read as "as.hammed". The letters "s" and "h" should have been parsed together as one unit, "sh". Separate parsing produces the two sounds /sə/ and /hə/ rather than the combined. /ʃ/. The pronunciation of the "a" in shortened form as /ae/ (rather than /e/) also results from a misparsing. The "a" should have been parsed. with the unit that contains the following "e" so that a lengthened translation. would occur utilising the "rule of e" in English. Since the "e" was parsed separately, it received its own phonetic translation. There are many other examples amongst the error corpus of comparable misparsing errors from RB, though in relation to certain words she was able to parse above a single letter level. For example, the letter string "*tion*" was often read correctly. However, in general parsing decomposed into units which were too small. This may be a common feature in surface dyslexia.

In addition to the incompletely developed parser, RB has an incompletely developed translator. For her translator to be perfectly developed there should be no invalid errors within the error corpus. However, not all errors were valid and there were mismatches between orthographic chunks and phonological segments. Also, within the translator, in selecting from valid alternatives, RB would sometimes select a lower frequency alternative rather than a higher frequency alternative. This resulted in a valid error, though not strictly a regularisation error. Amongst RB's errors, there were few examples of blender errors, in which there would be omissions or missequences in the component sounds of target words. The large number of neologistic responses however, does suggest an impoverished lexical check system.

Other surface dyslexics have been described who have even better development of the phonological reading route. In these cases, the dissociation between the development of the routes is clear and crisper. An explicit example is Temple's (1984c) description of a case of surface dyslexia in a child with epilepsy. The child, NG, was able to read regular words whether familiar or unfamiliar with perfect accuracy. Irregular words frequently provoked regularisation errors. However, all of NG's reading performance could be accounted for by the strict application of a rule-based system. His phonological route performed excellently. Control children of a similar reading age to NG showed small trends in favour of regularity effects but none showed the degree of regularisation effect that NG displayed. NG was also significantly poorer than the control children at reading irregular words. Finally, NG displayed homophone confusion. Eleven out of twenty-two words read correctly were defined as their respective homophones. NG's performance resembled the performance described by Bub, Cancelliere, and Kertesz (1985) at a particular stage in the reading deterioration of their Alzheimer's patient. More recently, Hodges et al. (1992) have investigated such literacy deterioration in more detail.

Shallice and Warrington have argued that acquired surface dyslexics are using a small orthographic unit as a basis for processing in the phonological route and have lost the ability to process larger segments. Applying a similar interpretation to developmental surface dyslexia, it could be argued in relation to their model and to Temple's (1985~) model that small orthographic units are being used as a basis for processing and that there is failure to establish the ability to process larger segments. This was seen within the corpus of errors made by RB, when discussing some of her errors in processing digraphs and her impairment in parsing.

The Seidenberg and McClelland (1989) connectionist model which represents the relationships between orthography and phonology in a series of distributed connection weights was able to produce a moderate parallel to surface dyslexia. Regularity effects were emergent properties and the model was also able to produce readings of unfamiliar non-words (van Orderi, Pennington, & Stone, 1990). We have suggested that RB's inability to process segments above a phonemic level contributes to her difficulty, and van Orden et al. (1990) showed that the availability of phonological representations at the phonemic level allows the generalisations to non-words and the apparent regularity effects. However, as Besner et al. (1990) emphasised the Seidenberg and McClelland (1989) network was not very good at reading non-words. It

therefore provided a poor model of those surface dyslexics with well established phonological reading routes, for whom non-word reading is better than word reading. The Plaut et al. (1996) model, which incorporates dual routes, has much better skills at reading non-words and can therefore provide a better model of surface dyslexia.

As mentioned earlier, Marcel (1980) has suggested that the reading performance of normal children often resembles that of developmental surface dyslexia. However, in the reaction time studies of Seymour (1986), it is clear that surface dyslexics (whom he refers to as morphemic dyslexics) have response times which lie outside those of normal children. Thus, although the overall qualitative pattern of surface dyslexia resembles the pattern of some normal children they are nevertheless distinguishable from them in quantitative measures. Furthermore, the discrepancy between the developmental surface dyslexic and the normal child becomes more apparent as development proceeds. The surface dyslexic's strategy remains in comparable format but the normal child's repertoire develops into an orthographic processing system or other theoretical equivalent.

In relation to Ehri's (1992) model, RB would have acquired phonetic cue reading but failed to acquire cipher skills. The connection between a word's spelling and its pronunciation would be partially established. There is some difficulty in explaining why this skill has not developed further. There is no evidence of any phonological impairment for RB (see further discussion later), so there is no obvious reason why the full links to phonological representations could not be derived. In relation to Perfetti's (1992) model the strength in non-word reading despite limitations in irregular word reading require explanation.

Long-term Effects

The increase in RB's reading age over time is given in Table 5.3. Subsequent to the analysis of her performance as presented above, RB was incorporated into a remedial year of intensive tuition outside mainstream schooling. Remediation began at the age of 10;8 and was maintained for a year. The first column of Table 5.3 indicates performance prior to the remedial academic year and the fourth column indicates progress at the end of it. A change in reading age over time is

TABLE 5.3
Sustained Dyslexia, Despite Remediation, for RB

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Chronological age	10;6	10;11	11;3	11;6	14;6
Neale reading age (accuracy)	7;8	8;7	8;11	9;11	10;1

also documented in this table. However, despite the increase in reading age the character of reading remained unchanged. RB continued to display surface dyslexia with impoverished ability to read by non-phonological systems.

Underlying Disorders Relevant to Impaired Lexical Reading

Some authors have suggested that a phonological processing disorder underlies developmental dyslexia (Stanovich, 1988; Wagner & Torgeson, 1987), in that all developmental dyslexics have phonological processing problems (Wilding, 1989, 1990). However, analyses of phonological problems have tended to be based upon group studies which mask variation in performance pattern within the dyslexias. It now seems clear that, in the form of developmental dyslexia called developmental phonological dyslexia (Temple & Marshall, 1983), there is also an oral phonological processing deficit and the nature of this deficit will be discussed later, following the discussion of phonological dyslexia itself. However, in many cases of surface dyslexia, there is no evidence of a phonological processing impairment.

It is unfortunate that the first detailed published case description of surface dyslexia (Coltheart et al., 1983) was a rather impure case and did also have phonological processing problems. For RB previously described, there were also some abnormal aspects to the functioning of her phonological reading route. This has raised the question of whether in surface dyslexia there is always an abnormality in the phonological reading route and indeed., whether there is always an abnormality in the phonological reading route in developmental dyslexia. If this were the case the distinction between the different developmental disorders might simply relate to differences in the development of the semantic reading route. However, the available evidence indicates that surface dyslexia is not always associated with impaired development of the phonological reading route.

The case of surface dyslexia in NG (Temple, 1984c) answers this issue. NG is a surface dyslexic but here the phonological route has developed perfectly but with marked impairment in lexico-semantic mechanisms. The surface dyslexic NG (Temple, 1984c), is no poorer than control children of a comparable reading age in reading non-words, so there is no impairment in his phonological reading route. Yet, he is dyslexic. The existence of children like NG enable rejection of the theory broadly held by developmental psychologists that reading disorders always result from phonological disorders and requires an amendment permitting the view that reading disorders often result from phonological disorders.

Often, the phonological discussions are based upon performance on phonological tasks outside the reading domain itself. Most frequently rhyming tasks are employed. In our studies, one such test of performance is assessed on the basis of a rhyme fluency task. In this task, 12 different individual words are dictated. Each contains a different central vowel. The child is asked to generate as many words as possible that rhyme with the target word, and is given one minute for each word. RB's fluency performance was assessed when she was aged 14 and had a reading age of 10;1. Control children with an average reading age of 10;6 were also assessed. On the rhyme fluency task, controls attained a mean score of 45.6 rhymes. RB produced 49 rhymes on this task, indicating no impairment on rhyme fluency.

Similar results are reported for other cases of surface dyslexia. Allan, the surface dyslexic studied by Hanley, Hastie, and Kay (1992), performed well on a series of tests of phonological ability including making rhyme judgements and constructing spoonerisms on Perin's (1983) test, showing intact phonemic awareness and ability to parse and manipulate phonemes. The case of surface dyslexia described by Goulandris and Snowling (1991) had no impairment in. phonological awareness. MI, the surface dyslexic described by Castles and Coltheart (1996), had normal performance on auditory rhyme judgement scoring 40/40 compared to a control mean of 38.5 (SD=1.18) and 28/30 on a phoneme deletion task also compared to a control mean of 27.8 (SD=1.14). The intact phonological skills in these cases of developmental surface dyslexia are further evidence of the need to revise the view that phonological problems are a consistent feature of developmental dyslexia. Lexical reading problems are not necessarily associated with problems in phonological awareness. Thus, surface dyslexics do not have impaired performance on oral phonological tasks.

It is generally assumed that reading was introduced into our civilisation after the end of the evolutionary processes which produced *homo sapiens* and the apparently superior cortical development. In this case, the reading mechanisms which have been discussed must be parasitic upon mechanisms which previously evolved within the brain to carry out alternative processes. If there is no underlying abnormality in general phonological processes, the question arises as to the nature of the abnormality of non-phonological processes that might underlie the impairments of surface dyslexia. What is the system whose impairment has led. to these difficulties with non-phonological processes?

Marshall (1984, 1987) gets around this type of discussion by suggesting that reading might have entered our cognitive repertoire far earlier than we had realised, but the absence of preserved written records has left us with no evidence of this early mastery. He suggests that the reading process is "preformed" and that experience in education merely fills out the system's content. Ellis (1985, 1987) has suggested that the reading skills required for lexical semantic processes are dependent upon systems which are adapted for analysing complex visual patterns. In support of this view, Goulandris and Snowling (1991) report impairments in both recognition and retention measures of visual memory in JAS, their case of surface dyslexia, though as Castles and Coltheart (1996) point out their case is a more convincing report of surface dysgraphia than of surface dyslexia. Castles and Coltheart (1996) found intact visual memory in their case MI, of surface dyslexia in a nine-year-old boy. Recognition memory was normal on the Warrington Recognition Memory Battery. Recall of patterns was normal on Benton's Test of Visual Retention and sequential memory was normal on the IPTA sequential memory test. Indeed on the latter, performance was in the top 1%. Furthermore, Dr S (Temple, 1992b), who has been discussed in Chapters 2 and 3, had severe impairment in visual memory but had intact reading skills, supporting a double dissociation between memory for complex visual material and word recognition skills.

Naming Deficits

Margolin, Marcel, and Carlson (1985) have discussed a possible association between one form of acquired surface dyslexia in adults and anomic difficulties. They have suggested a common deficit in the output lexicon which disrupts both processes. Naming difficulties in children with developmental dyslexia were discussed by Rudel (1985), who spoke of a subtle dysnomia. It has been found that dyslexics, as a group, respond less accurately and more slowly than chronological age controls on tasks which involve rapid automatised naming and the retrieval of verbal labels from the lexicon (Denckla & Rudel, 1976; Denckla, Rudel, & Broman, 1981). Wolf (1991) has shown that this deficit extends to comparisons with reading age controls as well as chronological age controls when letter and number naming is involved. Fourth grade dyslexic children were slower than second grade average readers in speed of naming letters and numbers. Thus, exposure to print is not an adequate explanation of the difference.

Ellis and Miles (1981) argued that naming speed reflected lexical encoding mechanisms. In their view the difficulty is prior to articulatory encoding and lies within the connection or translation of visual to lexical codes. Bowers and Wolf (1993) emphasised that processes underlying naming speed should not be subsumed under phonological processes, as occurs in some discussions, but should be more closely aligned with processes involved in establishing the automatic induction of good quality orthographic codes. Speeded naming is therefore believed to reflect the automaticity of name retrieval. Murphy, Pollatsek, and Well (1988) speculate that breakdown in the establishment of dyslexic readers' orthographic codes may be linked to a breakdown in the establishment of visual input logogens. These studies therefore emphasise the failure of input processes rather than the output processes discussed by Margolin et al. (1985).

Some support for an association of reduced naming speed and patterns of dyslexia with intact phonological skills, also comes from Wimmer's (in press) study of German children. The German dyslexic subjects studies had adequate phonemic decoding skill yet had digit naming speeds which were slower than reading age controls.

The specificity of the processing difficulties have been explored in several studies. Dyslexics perform at a similar level to average readers in processing stimuli that are difficult to name such as Hebrew letters. It is only with nameable stimuli that differences arise (Ellis & Miles, 1981). Griffiths (1991) compared dyslexics and reading age controls on three different cued retrieval tasks: graphemic, phonemic, and semantic. In the graphemic task, words had to be retrieved on the basis of a lower case letter cue projected onto a screen. In the phonemic task, the cues were initial letter sounds, In the semantic task, the cues were spoken words and the subject had to produce another word which was partially defined by the cue. Examples of cues were *big, noisy, soft,* and *sweet,* and examples of acceptable responses to these were *elephant, tractor, quilt,* and *toffee.* Performance with graphemic cues, was poor for dyslexic readers in relation to both control groups. However, although performance with the phonemic cues was also poor in comparison to chronological age controls, it was at a comparable level to that of reading age controls. Performance with the semantic cues, was actually better for the dyslexic group than for either of the control groups. Relative to good readers, dyslexics had impaired retrieval at a word form level, but enhanced retrieval at a semantic level. Katz and Shankweiler (1985) have also argued for the specificity of the naming deficit to orthographic material, finding no relationship between reading ability and naming when objects, colours, or animals were employed but a significant relationship with letters.

Wolf has attempted to explore the individual differences in naming skills, in relation to patterns of reading ability. In contrast to the Shankweiler studies, she has argued that name retrieval difficulties are evident in dyslexics even when picture naming is involved, although the effects may not be as strong as with orthographic material. Using the Boston naming test, Wolf and Obregon (1992) examined naming skills and comprehension of the same lexical items on a multiple choice test in eight dyslexic subjects. They also looked at reading of regular words, irregular words, and non-words. Several subjects had global reading difficulties which affected both irregular, regular, and non-word reading.

These subjects also performed very poorly on the Boston naming test but.performed well on the multiple choice comprehension test, indicating unambiguous retrieval deficits.

Wolf and Obregon (1992) also described a subject with preserved accuracy in reading phonologically regular and nonsense words but impaired accuracy in reading irregular words. Latencies exhibited the same pattern and were twice as long for irregular as for regular words. They note that this pattern of performance conforms to that of surface dyslexia. However, this subject performed at a normal level on the naming task, and did not display evident lexical retrieval difficulties in naming. It is possible that the confrontation naming task emphasised phonological skills more than the automaticity of retrieval required for speeded naming and conclusions are also tempered by the superior vocabulary knowledge of this subject, which averaged three years above his grade level. Thus, although naming was at an average level for age, it could be argued that it indicated a subtle retrieval deficit when compared with the actual levels of vocabulary knowledge.

However, support for Wolf and Obregon's (1992) apparent dissociation between surface dyslexia and naming impairments comes from our recent study of both executive skills and hyperlexia in Turner's syndrome (Temple & Carney, 1996; Temple, Carney, & Mullarkey, 1996; see also Chapter 4 for a syndrome description and analysis of spatial skills and Chapter 6 for a discussion of executive skills in Turner's syndrome). Nine- to 11-year-old girls with Turner's syndrome were found to be significantly impaired in comparison to controls in the rapid automatised naming of colours. Yet, despite the impairment in speeded naming, the children with Turner's syndrome were hyperlexic, according to the original definition of hyperlexia proposed by Silberberg and Silberberg (1967, 1968), in that they read at a level significantly above what would be predicted by their intellectual level and also at a level significantly higher than their peers both for material requiring phonological skills and, more importantly for the arguments here, for material requiring word specific knowledge, i.e. irregular words. So despite the impairment in speeded naming of colours, they do not have surface dyslexia. The pervasiveness of their automatised naming deficit in relation to other classes of material remains to be explored.

The specificity of any association between deficits in rapid automatised naming or confrontation naming and the impaired development of the lexical reading route in surface dyslexia therefore remains to be substantiated.

A variety of other earlier visual processes have also been suggested as being impaired in dyslexia (e.g. Lovegrove, Martin, & Slaghuis, 1986). However, they are not suitable as potential underpinnings for surface dyslexia as they fail to account for the material specific nature of the difficulties. Specifically, peripheral visual deficits could not account for the intact processing of non-words and regular words. In general, peripheral visual accounts of developmental dyslexia fail to explain the variation in reading performance in relation to the nature of the stimulus material to be read (Hulme, 1988). Hulme (1988) argued that when low-level visual impairments are reported, they are irrelevant correlates of the developmental dyslexias. Rare dyslexias arising from high-level visual impairment remain a possibility. Such a case is reported by Valdois, Gerard, Vanault, and Dugas (1995). Their IO-year-old dyslexic girl made reading errors dominated by visual paralexias. Significantly, the typical psycholinguistic dimensions did not affect the quality of her reading. There were neither regularity nor lexicality effects. The impairment was common across all stimulus material, with simply a frequency effect upon overall accuracy. Words could not be read automatically. The case of Valdois et al. (1995) was clearly not that of surface dyslexia.

Precise case descriptions of children with surface dyslexia have been limited in number, although the syndrome has now been described in relation to a variety of different European languages. It would nevertheless appear that developmental surface dyslexia is less common than developmental phonological dyslexia, which will be described next. Castles and Coltheart (1993) examined the lexical and sublexical reading skills of 56 developmental dyslexics and 56 normal readers. Eighty-five per cent of the dyslexic subjects showed a dissociation between their irregular word reading (lexical processes) and their non-word reading (sublexical processes). Of these 46% showed a surface dyslexic pattern (poor irregular word reading), whereas 64% showed a phonological dyslexic pattern (poor non-word reading). Of the total sample of dyslexics, 30% showed a surface dyslexic pattern, a rate higher than the case reports in the literature might suggest. Castles and Coltheart (1993) note that in some subjects for whom there is a dissociation, both skills are impaired with one being markedly more impaired than the other. Nevertheless, of particular interest, one in three of the dyslexic children had particular difficulty with one reading procedure in the absence of any difficulty with the other.

Overall, these results indicate that the patterns of surface and phonological dyslexia are not rare, spurious, and atypical anomalies but are encountered frequently within dyslexic populations. The results are consistent with those of Olson, Wise, Conners, and Rack (1990) who found greater independence of phonological and orthographic skills in a sample of disabled readers than within normal readers. Notably, Olson et al. (1990) found significant and strong heritability only for the phonological coding contribution to word recognition. It is impairment of these processes which are relevant to the discussion in the following section on developmental phonological dyslexia.

DEVELOPMENTAL PHONOLOGICAL DYSLEXIA

In contrast to developmental surface dyslexia, the major characteristic of developmental phonological dyslexia is a selective impairment of phonological reading processes.

The term developmental phonological dyslexia was first utilised by Temple and Marshall (1983), to apply to a case of a seventeen-year-old girl HM with a specific difficulty in reading. HM had normal speech, no known neurological abnormalities and was of good intelligence. However, she had significant difficulty in reading non-words aloud. Moreover, the pattern of her reading errors was dominated by paralexic responses and a substantive number of morphological paralexias. Rather than discussing this previous case in detail, a further case report will be presented which describes the teenager, JE. JE was briefly documented by Temple (1984a) but more extensive details are given here.

Case Report: Developmental Phonological Dyslexia, JE

JE was a 17-year-old, right-handed girl with no known neurological abnormality. There is a family history of reading and spelling difficulties. Administration of the Wechsler Intelligence Scale for Children revealed the following subtest profile for JE:

Verbal Tests		*Performance Tests*	
Information	**9**	Picture Completion	15
Similarities	16	Picture Arrangement	9
Vocabulary	10	Block Design	10
Comprehension	15	Object Assembly	13

(10 *is* an average subtest score, range 1–19, SD = 3)

Verbal IQ	15	Performance IQ	112
Full Scale IQ	116		

JE had fluent and articulate speech. She attained five *"O"* levels at school in Biology, English Literature, English Language, History, and Art, Subsequently, she went on to attend Chelsea Art College. In a discussion about Braque and Picasso, she made the following comments which give some minimal indication of her intact intellectual and vocabulary skills:

> They became very friendly and some of their early work, you can't teli the difference between; it is very difficult. Cubist painting tends to have much more life and much more feel about it. It can express anger with much more power than a conventional painting can. Cubism was criticised by the futurists in Italy and they said it wasn't art. But the cubists said that futurism wasn't art, while the constructivists said it all wasn't art.

At the time of assessment presented, JE's single word reading age on the Schonell Single Word Reading Test was 12;4. Tested one year later, in the absence of repeated daily practise in reading, while she was attending art college, performance had declined slightly and a Schonell reading age of 11;8 was attained. Performance has plateaued at this level.

Non-word Reading. JE was presented with the same three lists described for RB previously. In each case the non-words differed from the words by the alteration of only one letter. Overall, JE read 53/54 words correctly but only 30/54 non-words. Thus, JE displayed the major characteristic of phonological dyslexia, which is that non-words are significantly harder to read aloud than words i.e. there is a significant lexicality effect ($X^2 = 27.53$; $P<0.001$). Some errors to non-words were lexicalisations, e.g. *zan* →"tan"; *fip* →"flip"; *chait* →"chart"...."trait". Such lexicalisations are relatively common responses amongst developmental phonological dyslexics. JE was also given non-words to read aloud, which were either homophonic or non-homophonic with real words. Unlike other cases of both acquired and developmental phonological dyslexia (e.g. Temple & Marshall, 1983), she derived no benefit in the reading of non-words, if they were homophonic with real words.

Word Reading. Although JE was unable to read correctly the non-words *zan* and *fip,* she was able to read correctly words such as *disproportionately, overconfident,* and *categorically.* In contrast to her poorly established phonological reading skills, her lexical reading mechanisms were well established.

JE was presented with 434 words to read aloud. She made 49 errors. Of her errors, only 10% (i.e. five) were neologisms and the remainder were paralexias. Of the paralexias, 55% were morphological, in that the base of the word was read correctly but an affix was dropped, added, or substituted. The remaining errors were either visual paralexias in which stimulus and response shared at least 50% of letters in common or were visuo-semantic paralexias in which there was similarity between stimulus and response in both visual characteristics and meaning. Examples of JE's morphological paralexias were as follows:

weigh →“weight”	*instance* →“instant”
choir →“choirs”	*image* +“imagine”
jumper +“jump”	*banishment* →“banished”
sickness +“sicken”	*political* →“politician”

Visual paralexias included the following items:

adjective +“abject”	*archer* →“anchor”
fight →“fright”	*furnish* →“finish”
couch +“cough”	*chassis* →“chase”

It is evident from these visual paralexias that JE often produced irregular words as responses. It was not the case that she was producing a simplified regular word in response to an item which she did not recognise.

JE was also given the long words and non-words from Coltheart’s Lexical Decision Task to read aloud. It was clear that in deriving pronunciations, JE did not simply apply a rule based system, rather, there was activation of whole word items. Thus, for example, in attempting to read the word *belligerently,* JE produced the response “belly.gravely”. The word *miscalculations* was read as “miscellaneous.shun”. The word *undemocratic* was read as “under.macratic”. Similarly, in relation to non-words, the non-word *laborcolator* was read as “labour.curator”. The non-word *ramifationic* was read as “ramification.inic”. The non-word *electrifationic* was read as “electrification.onic”. And again, *dimeocrities* was read as “dimo.critic”. The generation of large word subcomponents within incorrect responses was also noted by Temple and Marshall (1983) in their original case description of phonological dyslexia.

Psycholinguistic Dimensions. On Coltheart et al.’s (1979) regular and irregular words, JE displayed no regularity effect, reading 36 regular items and 35 irregular items. In the case description of the developmental phonological dyslexic HM, Temple and Marshall (1983) pointed out that her reading was significantly influenced by the psycholinguistic dimensions of both imageability and frequency. For JE no such differences were evident, she performed equally well on high and low imageability items’ and on high and low frequency items. On all sections performance was relatively high. In this regard, developmental phonological dyslexics are like acquired phonological dyslexics in that the effects of psycholinguistic dimensions are somewhat inconsistent, JE was presented with the 40 items on the homophonic word list (Temple, 1984b) to read aloud and to define. She read and defined all stimuli correctly, displaying no homophone confusion.

Distorted Typescript. JE was presented with a set of 80 words written in four different formats: normal typescript; handwriting; reversed low, er case script; and reversed upper case script. The results of her performance are summarised in Table 5.4.

JE was not significantly impaired when handwritten stimuli were presented but was significantly impaired, when the stimuli were presented with the component letters typed in the reversed order. (Lower case, χ^2 = 14.7, P<0.001; upper case, χ^2 =11.38, P<0.001). It was the distortion that requires a sequential, analytical strategy to be activated, that created greatest problems for JE. This impairment in performance is relatively consistent across developmental phonological dyslexic cases, although it was less marked in the original description of HM (Temple & Marshall, 1983). It is relatively resistant to change over time and is a mode of detecting subtle reading impairments in apparently recovered adult phonological dyslexics (e.g. Temple, 1988a).

Many further cases of phonological dyslexia have been described in children in a number of different languages. Examples of detailed case descriptions are to be found in Snowling, Stackhouse, and Rack (1986), Campbell and Butterworth (1985), and Seymour (1986). Developmental phonological dyslexia is a pervasive form of developmental dyslsxia (Castles & Coltheart, 1993).

Theoretical Explanations. Developmental phonological dyslexia is not easily explained in relation to stage models of normal reading development, in which stages must be passed through in an invariant sequence. Whereas surface dyslexia can be described as arrestment of reading development at the alphabetic stage, phonological dyslexia cannot be explained in relation to arrestment at a particular stage of the Marsh et al. (1981), Frith (1985), or Ehri (1992) models, since in phonological dyslexia there appears to be development of orthographic reading skills, despite the failure to master alphabetic skills effectively. The only alternative is to suggest that phonological dyslexics have a significantly expanded logographic reading system which is able to incorporate thousands of words. However, no such logographic reading system has ever been described in normal children.

TABLE 5.4
Reading of Distorted Typescript by a Phonological Dyslexic

Stimuli	*Example*	*Number Correct*
Normal typescript	e.g. large	71/80
Handwritten		67/80
Reversed lower case	e.g. egral	49/80
Reversed upper case	e.g. EGRAL	52/80

A further alternative, is to suggest that there are different pathways through which children proceed in the acquisition of reading. Although the majority might go through the traditional routes described by Frith, Marsh, or Ehri and colleagues, for some children there may be greater emphasis upon orthographic mechanisms with less mastery of alphabetic stages. This general argument is similar in principle, though opposite in direction, to that discussed by Stuart and Coltheart in relation to the individual differences in the first phase of reading. Stuart and Coltheart (1988) argued that not all children start with a logographic phase but some go directly to using alphabetical principles. Here, we argue that there are also children who may start with a logographic phase but never develop into an alphabetic stage, proceeding directly to orthographic skill. Thus, in relation to the standard developmental models, the alphabetic skills of some children have been underemphasised at the start and for others they have been over-emphasised in later development.

This view also echoes the type of arguments proposed by Baron and Strawson (1976) in their discussion of Chinese and Phoenecian readers. The normal, adult Chinese readers described by Baron and Strawson (1976) show greater strength in the reading of whole words than in the mastery of non-word mechanisms. Such individual differences in the normal population may be relevant to discussions of alternative modes in the acquisition of information. Certainly, if a modular organisation is postulated in both child and adult reading systems, there is a priori reason why a specific module should have to be essential as a precursor for another module, if the two relate to semi-independent parallel reading systems.

In discussing phonological dyslexia in relation to adult models of normal reading, the disorder receives a relatively straightforward explanation by postulating relatively normal development of semantic, lexical, and direct reading systems but with impairment in the acquisition of the phonological reading route. This would represent a deficit in the functioning of the route marked as “3” (in Fig. 5.4) of Temple’s (1985~) model. Temple (1988a) has suggested that the abnormality in the phonological reading route could relate to an inappropriate parsing or translating mechanism, such that the units on which the systems operate are too large. Insufficient decomposition of the stimulus leads to the responses documented earlier in which whole words or morphemic components are found within responses, when trying to read aloud long unfamiliar words or non-words. Thus, whereas in surface dyslexia we see evidence of the system parsing at too small a unit level, in phonological dyslexia we see evidence of parsing at too large a unit level (Temple, 1988a).

The proportion of morphological errors amongst the error corpus for JE is substantial. These errors are a core and substantive element of overall performance. The morphological errors made by developmental phonological dyslexics are explicable in two alternative ways in relation to models of adult reading. One explanation postulates that affix-like endings are dependent upon processing in the phonological reading route (Patterson, 1982). This argument is based on the notion that such endings have low semantic content and meaning and are therefore more similar to non-words than to other morphemic entries. A parsimonious explanation can therefore be produced for the appearance of morphological errors in developmental phonological dyslexia by merely arguing that a well-established phonological reading route is essential for the correct reading of such items in a consistent fashion. In developmental phonological dyslexia, the prevalence of morphological errors and function word substitutions tends to increase in text reading (Temple & Marshall, 1983), just as it does for acquired phonological dyslexics. In normal adult readers, there is some suggestion that text reading reduces the involvement of normal phonological reading mechanisms. Normal subjects also begin to make occasional morphological errors, if reading text rapidly.

An alternative explanation for morphological errors is that in parallel with the morphemically based logogen system in the semantic reading route, there is a second channel which is processing affix-like components. This system is also argued to be impaired in acquired phonological dyslexia (Caramazza, Miceli, & Villa, 1986). With this explanation, it is necessary to postulate two deficits within the reading system in phonological dyslexia, both acquired and developmental, one to explain the non-word deficit and a second to explain the morphological errors.

Morphological reading errors create practical difficulties for phonological dyslexics in examination situations, since they may lead to paragrammatic misreading of examination questions which can result in inaccurate interpretation of examination questions.

Initial attempts to model phonological dyslexia within connectionist networks were limited in their success. It was possible to model the emergence of phonological skills in these systems. However, in phonological dyslexia, it was the failure of phonological skills to be mastered in a normal fashion, which had to be modelled. Besner et al. (1990) suggested that since the connectionist model of Seidenberg and McClelland (1989) was poorer than normal at reading non-words, the model’s performance actually resembled phonological dyslexia rather than normality, but this hardly provides an account of phonological dyslexia in relation to a model of normal reading. Perfetti’s (1992) connectionist model within a developmental framework faces similar problems.

In relation to Ehri's model (1992), there is only a visual-phonological route to reading. Phonological recoding is essential to develop this, and an amalgamation of spelling and pronunciation. In Ehri's terms the phonetic cue reading phase is not properly established. Thus, Ehri (1992) would have to predict a marked impairment in reading development in developmental phonological dyslexia. Yet, reading attains high levels. The model is not able to account for these high levels of word recognition skill but the simultaneously poor performance in non-word reading. Ehri argues that with any partial connection the reader will be slow and inaccurate. The nature of the inaccuracy is not specified and if it relates to a low level of errors within which there are morphological and visual paralexias, it has some validity, but overall in developmental phonological dyslexia such as JE's, word recognition is quick and accurate, which cannot be accommodated within Ehri's theory.

In relation to the revised connectionist model of Plaut et al. (1996), phonological dyslexia could be explained as reflecting impairment of their direct route, which maps orthography onto phonology through a set of hidden units, but with development of their semantic route, which maps orthography to semantics, through a different set of hidden units and then to phonology via a further set of hidden units. The semantic route can read words but not non-words. Besner (in press) notes that there are difficulties in explaining the acquired phonological dyslexics, who have impaired comprehension and a damaged semantic system but for whom there are no semantic errors, arguing that a triple route model is needed to account for such cases. Amongst developmental phonological dyslexia, such cases have not yet been described so, at present, the Plaut et al. (1996) model could account for the major characteristics of developmental phonological dyslexia. As yet, the dual route connectionist model has not been assimilated by a developmental psychologist into a more articulated model of reading development.

Long-term Effects. AH, a developmental phonological dyslexic (Temple, 1984b, 1985b, 1990c), has been followed up for six years since the original description of his case. At the age of 10, the proportion of paralexic errors in different categories was as follows: visual paralexias 60%; visuo-semantic paralexias 5%; morphological paralexias 15%; pseudo-morphological paralexias (in which letters resembling affixes, but which are not actually affixes, are substituted) *5%;* valid paralexias 6%. At the age of 16, the distribution of error types had shifted to look more similar to the pattern described for JE above. The distribution of paralexic responses was now: visual paralexias 27%; visuo-semantic

paralexias 19%; and morphological paralexias 54%. There were no regularisations.

In summary, as AH became older, there was no suggestion of his error distribution becoming more like that of a surface dyslexic. Instead, it resembled the picture of other described phonological dyslexics. Overall reading age did improve. On the Schonell reading test, a reading age at the age of 10;2 of 8;2 improved by the age of **16;3** to a reading age of 13;8. However, AH was still impaired in the reading of non-words, despite what appeared to be an almost adult level of competence in the recognition of real words. Thus, a significant lexicality effect also persisted with age. Errors to short non-words included both lexicalisations and non-word responses. As noted for JE, neologistic responses to long, low-frequency words or non-words included substantive word subcomponents (e.g. *existentialism* →"extentionolism"; *imparsonious* →"impassionous"; *cirsumicular* →"cirmycircular").

The stability of the pattern of reading seen in phonological dyslexia over time has also been observed in other studies. Hulme and Snowling (1992) reported a follow-up study of a case of developmental phonological dyslexia. Their case, first seen at 8 years was followed through to 13 years. He showed a "highly stable form of dyslexia characterised by a slowly expanding sight vocabulary in the face of massively deficient non-word reading skills" (p. 63).

Persistence of this overall pattern of developmental phonological dyslexia into middle age was described by Temple for a 47-year-old, right-handed man, JR (Temple, 1988a). JR was a self-employed man who ran his own building firm but recalled having difficulty with reading from the start at school. Mathematics and woodwork were unproblematic. After school he attended a technical college for carpentry and joinery. He obtained an intermediate level and went into the army. However, he continued to experience difficulty with reading and spelling. He had had no serious illness, head injury or neurological disorder. He had four children, two of whom had difficulties at school with reading and spelling. A third child was autistic.

JR was found to be of normal intelligence with fluent and articulate speech and no anomia. He displayed the characteristic symptomatology of developmental phonological dyslexia with an impairment of non-word reading in relation to word reading and with reading errors dominated by morphological paralexias, neologistic responses containing large word components and some visual paralexias. Presented with 25 items in lower case typescript, he was able to read 96% correctly but when these same items were presented in reversed typescript, he was able to read only 24% correctly. Thus, the major features of developmental phonological dyslexia may be sustained throughout the life span and what is observed in a 10-or 12-year-old child is not necessarily a delayed and deviant development that will simply resolve with time.

Nevertheless, in the longer term, the developmental phonological dyslexic may be less impaired by their pattern of deficit than the developmental surface dyslexic. At the age of 10, RB and AH were compared by Temple (1984b). RB, as described earlier, was a developmental surface dyslexic and AH, as also mentioned previously was a developmental phonological dyslexic. At the age of 10, the children were of comparable ability, with a similar reading age and a similar spelling age. Indeed had these children been being assigned to some type of remedial trial, it would have seemed that they were well matched on conventional test results and that one could validly have been assigned to one condition and one to the other. A detailed analysis of the nature of their reading though, showed up the numerous, sharp double dissociations in performance that there are between surface and phonological dyslexia.

Retested at the age of 14 (Temple, 1987), it was evident that AH had made more substantive progress than RB, despite the intensive remediation which RB had received for one year in the earlier portion of the intermediate period. At the age of 14, AH had a reading age of 11;8 but RB had only progressed to a reading age of 10;1. One possible explanation for the difference is that, as the demands made upon the reading system increase in a language like English, the lower frequency items which are expected to be incorporated into the vocabulary include a larger number of irregular items. For a developmental surface dyslexic, these produce particular difficulties, whereas for a developmental phonological dyslexic, they are no more problematic than other items and indeed, if it is argued that irregular words are more visually distinct from other words than regular words, then it may even be easier for the developmental phonological dyslexic to add such items into their vocabulary. Thus, while the developmental phonological dyslexic continues to be hampered by the grammatical aspects and affixes associated with words and has difficulty in working out unfamiliar scientific terms, unfamiliar technical terms, or unfamiliar names, they are nevertheless able to build up a large repertoire of recognisable items within their recognition system for words. The surface dyslexic is constrained by the laborious requirements of decomposing words and applying a rule system to attain their pronunciation which may reach a plateau in the possible level of attainment and effectiveness.

Underlying Disorders Relevant to Impaired Phonological Reading?

As mentioned earlier, there has been much contemporary interest in the possibility that a basic phonological processing deficit may underlie developmental dyslexia. As argued previously, we do not have evidence for a phonological processing deficit in cases of surface dyslexia. Nevertheless there is evidence for such an impairment of this sort in cases of developmental phonological dyslexia and since these cases represent the more common pattern of developmental dyslexia (Castles & Coltheart, 1993) this may account for the group effects which are seen on group analyses.

JE, described earlier, was tested when her reading age was 12;4, with a fall a year later to 11;8. Temple, Jeeves, and Villaroya (1989) document control results from normal children age 11 with a reading age of 11;11 on the rhyme fluency task. They report a mean fluency score of 61.25 with a standard deviation of 2.8. JE attains a score of 47 on rhyme fluency. She therefore clearly has an impairment in producing rhymes. An impairment in rhyme fluency is also documented for AH, who with a reading age of 11;8 produces only 33 rhymes (Temple, 1987). Other researchers have also documented rhyming impairments in developmental phonological dyslexia.

The theories about the relationship between reading disorders and phonological or phonemic difficulties have been expressed in a number of formats. As has been discussed previously, our view is that if present at all, they may be characteristic of only a subsection of dyslexics. Nevertheless, since there is considerable current interest in this issue, the different theoretical formulations will be discussed, despite the dominance of group studies, in their investigation.

Impaired Phonological Awareness as a Cause of Dyslexia. Bradley and Bryant (1983) argued that the ability to categorise sounds is causally related to reading ability. In a further study, they found that sensitivity to rhyme was linked in development to awareness of phonemes and that both of these skills influenced later reading development (Bryant, MacLean, Bradley, & Crossland, 1990). Snowling (1980) has also argued that a deficit in phoneme awareness would hinder reading development, though she is more explicit by proposing that it would be the development of grapheme–phoneme skills which would be impaired, a proposal more in keeping with the data and models discussed above.

This view is also compatible with the evidence from cases of callosal agenesis, a disorder in which there is congenital absence of the corpus callosum. Jeeves and Temple (1987) suggested a consistent deficit across acallosal adults in explicit phonological processing as reflected in initial letter fluency tasks and rhyming tasks. Temple et al. (1989) confirmed such deficits in children with callosal agenesis. Despite these problems with phonological awareness, their reading ages and word recognition skills were at a normal level for age (Temple, Jeeves, & Villaroya, 1990). However, further analysis of the nature of reading performance indicated preservation of lexicality effects beyond the normal age and an impairment in non-word reading, reflecting deficiencies in the acquisition of orthographic–phonological correspondences (Temple et al., 1990). Thus, these children display relatively pure phonological dyslexias, if the term can be applied to children who are actually reading at age level. Their data are consistent with the view that impairments in phonological awareness may lead to impaired development of the phonological reading route.

For some children, training in phonemic segmentation skill is said to lead to improvements in learning to read (e.g. Bradley & Bryant, 1983; Brown & Felton, 1990). However, the evidence that training in phonological awareness leads to selective improvement in reading skills is in doubt (Bryant & Goswami, 1957; Hulme, 1987, 1988). The effectiveness of such training in severe cases of phonological dyslexia is even more debatable, as these disorders may be resistant to substantive improvement in phonological skills, proceeding instead by an ever expanding sight vocabulary as discussed in the follow-up studies mentioned earlier (Hulme & Snowling, 1992; Temple, 1990c).

Hatcher, Hulme, and Ellis (1994) found that in a remediation study of poor readers, intervention involving training in phonological awareness only generalised to a significant improvement in reading when training in reading had also been involved in the intervention. They conclude that "intervention to boost phonological skills needs to be integrated with the teaching of reading, if they are to be maximally effective in improving literacy skills". Training in phonological awareness alone did not produce a significant improvement in reading skill.

Reading as a Cause of Phonological Awareness. Other theorists have argued that phonological deficits are not a cause of reading problems but are a consequence of them (Morais, Bertelson, Cary, & Alegria, 1986; Morais, Cary, Alegria, & Bertelson, 1979). Their case is that learning to read in an alphabetic system provides the training which enables phonological awareness to develop. In the absence of an alphabetic writing system, phonemic segmentation skill may not be acquired naturally (Read, Yun-Fei, Hong-Yin, & Bao-Qing, 1986), though for children learning a syllabary, the skills may emerge later in school development, well after the time of their appearance for readers of alphabetic scripts (Mann, 1986).

However, dyslexics may not develop phonological awareness as a consequence of reading development. Bruck (1992) reports that dyslexics do not develop the same level of phonological awareness as younger normal children matched for reading level. Even adult dyslexics with fairly high levels of word recognition skill show phonemic awareness deficits. For normal subjects, phonological awareness increased with age and reading ability. For dyslexic subjects there was no systematic association.

Phonological Awareness as a Cause of Reading as a Cause of Phonological Awareness. Goswami (1991) suggested that the associations may differ dependent upon the type of phonological awareness being addressed. She argued that there are two critical levels of phonological awareness. The phonemic level of awareness, where words are broken into their smallest constituent sounds: may be a consequence of reading development. However, an intrasyllabic level of awareness, at which single syllables are broken into onset (initial consonant or consonant cluster) and rime (vowel and final consonant or cluster) may be predictive of reading ability. Goswami (1986) reported that pre-readers could form analogies between the ends of words. Fox (1994) pursued the issue of phonological discriminations in relation to positions within words, and found that dyslexics have much greater difficulty in processing the phonological characteristics of the ends of words in cross-modal tasks, than the beginnings of words.

Bruck (1992) found that dyslexics do eventually acquire onset–rime awareness following reading development but fail to develop phonemic awareness. Despite the onset–rime skills they remain dyslexic and despite the development of word recognition skills they remain impaired at phonemic awareness. It is not clear how these results, are compatible with Goswami's (1991) view. Despite, the development of onset–rime skills, there is not a disappearance of their dyslexia, and an impairment in this aspect of processing is therefore insufficient to account for their reading difficulties. However, although Goswami argues that onset–rime skills are predictive of reading ability in the normal population, it remains possible that an extension of the prediction to dyslexics is inappropriate or that the degree of onset–rime skills of Bruck's (1992) adult dyslexics provide the basis to enable their reading skills to improve, even if they are insufficient to eliminate the dyslexia. The impairment in adult dyslexics in the development of phonemic awareness (Bruck, 1992) indicates that the development of phonemic awareness is not a necessary consequence of improvement in reading skill.

With some similarity to Goswami (1991), in the Perfetti (1992) model some computational phonemic knowledge is needed to develop the initial functional lexicon but explicit phonemic awareness develops through experience of alphabetic stimuli.

Stuart and Coltheart (1988) argue that the conflicting views on the direction of causality can be resolved without the need to postulate different levels of awareness. They argue that phonological awareness and reading acquisition have a reciprocal interactive causal relationship not a unidirectional relationship. They see nothing contradictory in the notion that teaching phonological awareness accelerates reading acquisition but that learning an alphabetic script also causes people to be more phonologically aware than those learning other scripts or no scripts.

However, there remains a critical issue as to whether phonological awareness accelerates reading development or is an essential prerequisite. It is simply beneficial or is it necessary? Or expressed another way, is a deficiency in phonological awareness necessarily causal in producing reading disorder?

Bishop and Adams (1990) explored literacy skills in children who had had impaired language development at four years. They found only weak links between expressive phonological disorders and later ability to read either meaningful text or non-words. Cossu, Rossini, and Marshall (1993) argue more explicitly that phonological awareness is not a necessary prerequisite for reading development. They report that adequate reading of words and non-words, at least to a level characteristic of normal seven-year-olds, can be established by children with Down's syndrome despite their failure on tests of phonological awareness. They also report that, in children of limited intellectual abilities, advanced reading skill can be found in children without phonological awareness skills (Cossu & Marshall, 1990). They conclude:

> not all children depend upon phonological awareness in order to learn to read. If it is agreed that different children learn to read in different ways and that phonological awareness may play little or no role with some children, then we have no quarrel with assigning some importance to phonological awareness in the reading development of other children. (Cossu, Rossini, & Marshall, 1993, p. 135)

Further, the ability of their cases to read non-words as well as words counters the suggestions of deficits in phonological awareness as causal in even a restricted component of reading acquisition, namely grapheme–phoneme correspondences or the phonological reading route (Snowling, 1980; Temple et al., 1990).

DEEP DYSLEXIA

When deep dyslexia was first described in acquired form by Marshall and Newcombe in 1966, it generated a considerable reaction and through the 1970s and 1980s many research studies in the acquired neurological literature have focused upon the characteristics of this disorder, and the intriguing semantic errors that are generated on single word presentation. When for example, presented with a word such as parrot, the deep dyslexic may read it as "canary". There have now been descriptions of acquired deep dyslexia in a range of languages, but this syndrome has been harder to interpret in a simple way in relation to contemporary models of adult reading. It would be relatively easy to describe in relation to a developmental model of reading acquisition, since in some ways its characteristics represent reading, that could be described as reflecting the early stages of logographic reading. The cases, however, of developmental deep dyslexia in the literature are sparse.

Johnston (1983) described an 18-year-old girl with a reading age of 6;2 who could read no non-words. On testing with nearly 400 single words, CR made five semantic errors; one had a visual component (*office* →"occupation"), One so classified was a function word substitution and two involved the same word pair. The final example was a number substitution. Siegel (1985) described six children aged between 7;0 and 8;9 who had no phonological reading skills and made a few semantic substitutions and other errors characteristic of acquired deep dyslexia. Full individual data and precise error rates were not given. Neither of these papers demonstrated that the semantic error rate was above chance, when compared to performance of normal children. Thus, the degree of abnormality of the cases is unclear. Siegel (1985) suggested that her cases differed from normal. Although quantitative data was not reported, she looked at the reading performance of 64 children aged six to eight years and concluded that beginning readers tend to make visual errors involving the confusion of vowels. However, the involvement of chronological rather than reading age controls means that these children may already have developed some phonological reading skills.

A particularly convincing example of developmental deep dyslexia has been described by Stuart and Howard (1995). Their case KJ, a 13-year-old girl, had a 24% semantic error rate. She also made visual, morphological, visual and/or semantic errors, visual then semantic errors, and function word substitutions. She was unable to read any non-words. She showed no evidence of any attempted use of a phonological reading strategy; producing no neologisms, never sounding out a word, and producing no regularisations. Therapy experiments suggested that new words could only be learnt where there was extensive semantic representation suggesting that both a phonological and a direct lexical route were unavailable.

The case report given below provides an example of a case of developmental deep dyslexia.

Case Report: Developmental Deep Dyslexia KS

KS (Temple, 1988b) is a right-handed boy from a right-handed family. He is the eldest of three children and there is no family history of epilepsy, mental retardation or specific learning difficulties. Milestones were considered to be normal with first words appearing at 8–9 months, and a large vocabulary of single words established by 18–24 months. There is no record of head injury. Concern about hearing arose at four years and grommets were inserted following the detection of hearing impairment. Re-testing at age nine, indicated that KS was having difficulty with speech less than 40–45dbs. New grommets were inserted at this age. On examination at age nine, by a consultant in paediatric neurology, no neurological abnormality was found. No chromosome abnormality was found on genetic testing. However, total ridge count was low although mother's count was normal. Skull X-ray showed no abnormality. CT was normal. Sleep pattern and growth were satisfactory. On the Wechsler Intelligence Scale for Children, KS was found to have borderline intelligence with a Verbal IQ of 75 and a Performance IQ of 78. Subtest scores were as follows:

Verbal Scale		*Performance Scale*	
Information	5	Picture Completion	6
Similarities	8	Picture Arrangement	9
Arithmetic	4	Block Design	3
Vocabulary	6	Object Assembly	9
Comprehension	7	Coding	7
Verbal IQ	75	Performance IQ	78

(10 is an average subtest score, range 1–19, SD=3)

On Raven's Coloured Matrices, KS attained a score of 85 and on the Peabody Picture Vocabulary Test an IQ of 88. These suggested that there was not general depression of intellectual function that extended to ail tasks. Reading age on the Schonell Single Word Reading Test at the age of nine years, was 5;2 with only two words identified: *tree* and *flower.* Presented with 300 words to read aloud, most were refused. 29 words were read correctly: 19 were highly imageable, high frequency nouns: *dog, window, door, roof, chimney, river, egg, friend, field, cat, queen, boy, nurse, caravan, frock, zebra, cake, doll, mother;* 3 were colour names: *blue, red,* and *green;* 1 was an adjective: *pretty;* 1 was a verb: *play;* 5 were function words: *of, by, get, we,* and *him.* Of the 77 overt errors all but two were paralexias and none were neologisms; 5% were semantic (e.g. *eye* → "blue"), 3% were visuo-semantic (e.g. *fresh* → "flowers"), and 3% were morphological (e.g. *tree* → "trees"). The largest error category was visual paralexias, with 39% of errors being of this type. In addition, 9% of errors were function word substitutions (e.g. *the* → "and") and 12% of errors were classified as visual plus semantic errors (e.g. *clue* → "red" [via blue]).

KS only produced a restricted repertoire of words as responses, Random pairings of the stimuli with which he was presented and the possible responses he might make enabled a series of random word pair items to be generated, which could then be subjected to an error classification and compared with the responses of KS. Such a comparison indicated that the incidence of errors with a semantic component was significantly above chance. The error pattern was also within that span of reported cases of acquired deep dyslexia.

In addition to the nature of the overt reading errors, other characteristics of deep dyslexia were also displayed. Non-words could not be read and letters could not be sounded. The data from KS were also compared with the data from normal children described by Seymour and Elder (1986). Seymour's and Elder's normal children were aged 4;6–5;6 and had been taught by a method emphasising sight vocabulary, with no explicit mention of letter sound associations. On average, 2% of the normal errors from these children had a semantic component. For KS the figure was 17%.

On text reading, the semantic error rate increased to 20% with an increase to 69% of function word substitutions. Visual errors declined to 4%. There is no comparable data for acquired deep dyslexics or beginning readers.

Theoretical Explanation. Developmental deep dyslexia can be explained in relatively simple terms in relation to the models of both Marsh and Frith by postulating an arrestment at the logographic stage of reading development. Alphabetic strategies have not been acquired. There is only a limited repertoire of words that can be identified. These are of high salience and may occasionally generate semantic errors. In this regard, the arrestment appears closer to stage two in the Marsh model than stage one. At this stage, there may be a meaning based relationship between the words that are substituted and visual cues are relevant in those words that are substituted. This was also seen in the data of KS. Such a distinction is not possible in Frith's models since stages one and two are combined into her logographic phase, As noted earlier, Wimmer and Hummer (1990) have argued that a logographic strategy for normal or poor readers is very limited and does not arise naturally when the writing system is phonologically transparent as in German and grapheme–phoneme correspondences are part of the instruction. Others also question the existence of a logographic reading stage within normal development (Stuart & Coltheart, 1988). The data from the developmental deep dyslexics indicate that it is a possible first stage in reading development even if it is relatively uncommon within normal readers for it to be to expressed in this way.

The theoretical interest in the disorder and the rare incidence of its report suggest that developmental deep dyslexia is indeed of low frequency of occurrence. Temple (1988b) has suggested that the combination of deficits which are required to generate it are unusual in combination and that when combined may be sufficiently intense to produce a non-reader rather than a dyslexic. KS appears to have hearing abnormalities which have required the insertion of grommets. Furthermore, there is also profound deficit in visual memory. Thus, he may have a combination of deficits which makes it very difficult for reading to become established in the first place. However, KJ (Stuart & Howard, 1995) had comparative strength in visual short-term memory and had no known hearing impairment, so this explanation cannot account for the performance of their convincing case of developmental deep dyslexia. Stuart and Howard (1995) also note that, unlike KS (Temple, 1988b), KJ's reading impairment was resistant to treatment aimed at improving phonological skills.

In attempting to explain developmental deep dyslexia in relation to an adult model of reading, one encounters the same difficulties that are encountered in explaining acquired deep dyslexia. Regardless of the model that is suggested, multiple deficits are necessary to account for the broad range of features, though all emphasise the absence of the phonological reading route.

In the case of developmental deep dyslexia, it is not clear that utilising an adult framework is particularly constructive in helping us to understand the nature of the disorder. However, although it has been argued in relation to acquired deep dyslexia that the complex of symptoms involved make it difficult for this disorder to provide information about normal function, with the use of a connectionist model Plaut and Shallice (1993) have argued that symptom patterns can arise from functionally distinct lesions because of the overall organisation of the system. They show that in deep dyslexia many of the characteristics of the syndrome can be explained with a connectionist model, given only one other major assumption concerning the number of features in the semantic representation of different classes of words. It is not yet clear whether such a model could be applied to a developmental system.

HYPERLEXIA

The term hyperlexia was first used by Silberberg and Silberberg (1967) to refer to children whose word recognition abilities are in advance of their abilities in comprehension. Aram and Healy (1988) reviewed cases of hyperlexia, noting that written words are recognised at a level beyond expectation on the basis of intellectual ability. Hyperlexia has most frequently been observed in children with autism, though the two conditions are also dissociable. Theoretical discussion has addressed the relationship of hyperlexia to generalised language disorder (e.g. Richman & Kitchell, 1981). Cossu and Marshall (1986,1990) argue that the emergence of these precocious skills in children with otherwise severe cognitive and language difficulties supports the modular organisation of reading and writing and their independence from other cognitive abilities. Snowling (1987) has emphasised the contrast between dyslexia and hyperlexia, with dyslexia being associated with poor accuracy but good comprehension for the material read, but hyperlexia characterised by high accuracy but poor comprehension for the rnaterial read, a view confirmed by Aaron, Frantz, and Manges (1990). Healy, Aram, Horowitz, and Kessler (1982) found that hyperlexic children performed equally poorly on auditory and visual comprehension of language.

Aram, Rose and Horowitz (1984) have described a case of hyperlexia, in which reading has a similar character to that of surface dyslexia. Others have also explored this possibility (Goldberg & Rothermel, 1984; Welsh, Pennington, & Rogers, 1987). In contrast it has also been suggested that hyperlexia may form a parallel to the acquired reading disorder, direct dyslexia (Ellis, 1984; Marshall, 1984). In direct dyslexia, there is impairment of the semantic reading route, sometimes as a consequence of dementia, yet there is preserved ability to read irregular words suggesting preservation of a non-phonological reading route that bypasses semantics (Schwartz et al., 1980) (see Fig. 5.3 and 5.4). In hyperlexia, despite poor development of systems involved in extracting semantics from reading, pronunciation is of high accuracy.

Exploring these contrasting views of hyperlexia, Temple (1990a) reports a case of hyperlexia in a non-autistic child, for whom there was no significant regularity effect and no evidence of the over-reliance upon phonological reading mechanisms, characteristic of surface dyslexia. Words were read aloud correctly, which could not be understood from either auditory or written format. This was also true for irregular words. Significantly fewer irregular words could be defined correctly than could be read aloud correctly, despite a very loose criterion for the acceptance of a correct definition. This suggests direct reading route development. However, as Temple (1990a) points out the expanded phonological reading routes of Shallice et al. (1983) and Temple (1985~) could read the majority of the irregular words involved in the comprehension dissociation. These phonological reading routes (as discussed earlier) permit translation upon units above the level of the grapheme and the Temple (1985c) model posits a range of potential translations, which may be serially attempted in relation to frequency. Thus, an alternative explanation is that the hyperlexic had developed a sophisticated phonological reading route.

In Temple's case comprehension of single words is much better than comprehension of sentences. Temple (1990a) argues that semantic comprehension is relatively normal, but that it is syntactic comprehension which is deficient, arguing for the modularity of these Components during acquisition.

Seymour and Evans (1992) have conducted a detailed study of a non-autistic child with hyperlexia and his school peers. They argued that the child progressed towards an orthographic phase of reading development more rapidly than his peers and appeared to omit aspects of an alphabetic phase. He showed significantly less evidence of overt sounding out than his peers, which had been taken as an index of alphabetic processing. His reaction time distributions were also more convergent than his peers, suggesting to Seymour and Evans the establishment of an orthographic framework rather than a dual (logographic + alphabetic) process. They found no evidence of semantic deficit in the processing of single words but greater difficulty with sentences. This was consistent with Snowling's (1987) proposal that the semantic deficit in hyperlexia is located at a sentence or text level, comprehension of single words being normal.

Seymour and Evans (1992) discuss their results in relation to several models of reading. They point out that the connectionist model of Seidenberg and McClelland (1989) is essentially a model of hyperlexic reading since the orthographic system operates without the support of a semantic or contextual level. However, the success of the normal peers, in the Seymour and Evans study, in non-word reading at a time when their word reading vocabularies were relatively low, could not be accounted for by the Seidenberg and McClelland model without the incorporation of an additional alphabetic principle, in effect reinstating a dual-route model. Seymour and Evans (1992) further argue that for their hyperlexic there is no evidence of interdependence of the semantic and orthographic systems supporting modularity within the overall system. They conclude that an orthographic system may develop normally in the absence of a semantic level but that the inclusion of an alphabetic process would be expected to convey an additional advantage.

Temple and Carney (1996) have documented hyperlexia in Turner's syndrome. Reading levels were significantly above those predicted by age and intelligence, and significantly above control levels. Reading accuracy was also significantly better than controls for both non-word reading and irregular words reading. Thus, hyperlexia in Turner's syndrome has neither the pattern of surface dyslexia nor of direct dyslexia but appears to reflect genuine hyperdevelopment of a skill. Further, reading comprehension was significantly better than controls indicating no necessary links between hyperlexia and a disorder of comprehension. The hyperdevelopment of reading and certain other linguistic skills in Turner's syndrome is counterbalanced by their selective spatial deficit (Temple & Carney, 1995).

IN CONCLUSION

Hinshelwood's (1917) historical analysis of the developmental dyslexias emphasised their relationship to the acquired dyslexias. Further, he described the components of a cognitive reading system within which there were separate subsystems for processing components and attempted to explain the patterns of reading impairment seen in the developmental dyslexias in relation to this model. He was thus an early user of cognitive neuropsychology applied to children even though he predated the cognitive revolution itself.

There continue to be debates regarding the diagnosis of the developmental dyslexias, with concern about the utility of an I&-based classification system. However, despite the arguments about classification, an incidence of 6% is reported, with a male to female ratio of 2 or 3:1 (Lewis et al., 1994). Evidence for a biological basis for the disorder is now extensive, with support from genetic, electro-physiological, post-mortem, MRI, and PET studies.

Current models of normal reading differ in format. There continues to be reference to the traditional stage models (Frith, 1985; Marsh et al., 1981) of the development of reading, which argue for a single series of invariant stages through which every child must pass. In contrast dual and triple route models of reading recognise different ways in which words might be read aloud correctly, via either transformation of orthographic segments to phonological segments, or via semantic activation and thereby to a phonological representation, or directly from word detectors to phonological representations (Temple, 1985c). Connectionist models were derived from analogy theory and in the earlier formulations incorporated only one route for reading (Seidenberg & McClelland, 1989). However, these formulations had difficulties in generating good non-word reading and in accounting for the patterns of the acquired dyslexias. A revised connectionist model (Plaut et al., 1996) incorporates two routes to reading. Analogy theory and an earlier connectionist model have been partially integrated into models of reading development (Ehri, 1992; Perfetti, 1992), which as a consequence suffer from the weaknesses of these earlier formulations.

Three different forms of developmental dyslexia have been identified, which parallel those seen within the acquired dyslexias. In surface dyslexia, there is an impairment in irregular word reading, but no lexicality effect. Errors are dominated by regularisation/valid errors. There is confusion in the comprehension of homophones. Distortion of the global characteristics of words does not impair reading Performance. In contrast, in phonological dyslexia, there is no regularity effect but an impairment in reading non-words. Errors include morphological errors. Distortion of the global characteristics of words can impair reading performance. Deep dyslexia is characterised by complete inability to read non-words and by the appearance of semantic errors in reading single words aloud.

In relation to standard developmental stage models, deep dyslexia could be interpreted as logographic reading and surface dyslexia could be interpreted as alphabetic reading but, in phonological dyslexia, orthographic reading has been attained without mastery of alphabetic principles. This pattern of performance violates such models.

In relation to the multiple route models, surface dyslexia is interpreted as reflecting impaired development of the lexical and semantic reading route with consequent over-reliance upon the phonological reading route. Phonological dyslexia is interpreted as reflecting impaired performance development of the phonological reading route, with over-reliance in lexical and semantic reading routes. Deep dyslexia reflects absence of both the phonological and the direct route and use of an isolated and intrinsically unstable semantic route, or an isolated and damaged semantic route. The double dissociations seen within these pattern of dyslexia could not be explained within the older connectionist models, but the new dual route connectionist model permits an explanation similar to a conventional dual route explanation, but without the flexibility of a triple route. The evidence for the developmental independence of the phonological and semantic reading routes is therefore strong, incorporating a modular organisation to the reading system within development.

In terms of underlying causative factors, it has been suggested that surface dyslexics might have poor visual memories and/or poor naming skills. However, neither of these suggestions is consistent with current data. It is, however, clear that in surface dyslexia there is not

impairment of phonological skills and that these are therefore not the causal impairment in all cases of developmental dyslexia. In phonological dyslexia there is good evidence of impairment in phonological skills within both reading and purely oral tasks. This may impair the development of the phonological reading route, though despite this normal levels of word recognition may be attained.

Temple, C. M. (1997). Reading disorders. In Developmental cognitive neuropsychology (pp. 163-223. East Sussex, UK: Psychology Press.