

## Dyslexia: Characteristics and Causes

"I've always had problems reading. I remember second grade starting off I had problems. By third grade I started into a special class.

"To read a word I don't know, I try to do a real quick sounding out, and then try to read the rest of the sentence and try to get it by context. I see if maybe I've heard the word or if it sounds anything like that. If not, if I still can't get it, if I still can't find anything, I try to make something in my head that might justify it for the next time I come to it in the reading."

*--a dyslexic college student*

Dyslexics, like the student quoted above, have inordinate difficulty reading and learning to read. The difficulty is not only extreme but unexpected, too, because their ability to learn other school subjects, such as arithmetic, indicates that they are smart enough to learn to read.

The dyslexic's reading problems appear in the early school years and are increasingly evident beyond third grade, when other children of similar intelligence have mastered the rudiments of word encoding. Many dyslexics have difficulty mastering symbol sound correspondences, especially the more complex ones that are dependent on the context.

Dyslexics often have other language-related problems. They have trouble in spelling, and their handwriting is sometimes poor, containing awkward, irregularly spaced letters, misaligned words, and incorrect punctuation, as shown in Figure 12.1. Some of these problems improve with schooling and age, although they are sometimes still evident in a highly educated adult dyslexic.

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**Overview** In the first section, **Who is Dyslexic?** We will describe the major approaches to defining *dyslexia*, which reflect different hypotheses about its nature and cause. Moreover, these different approaches may lead to different groups of subjects being selected for study and, consequently, to conflicting results in the research literature.

They loved their children I know  
 If they don't it shows don't show.  
 If they were bad  
 it made them mad and sad.

I know that they shall live forever in bliss  
I know because I have seen their kiss.  
We show our love for them in many ways  
by writing poems and giving presents on their birthday

London  
The Plague of A. Clarke  
In the Plague of London  
lots of ppl died the ppl were  
red marks on their door  
and the ppl were  
and ppl were in  
was like the way  
and the church was full  
so they had to big  
pig house to put the  
ppl in the house.  
A fire to London  
The fire was a good  
thing in my way by cos  
it got out the fire  
the fire was 5 to 6  
cos the water was not  
good. The fire was  
200 there had 1000 people

low foling low foling  
 the gran of red  
 a capite or ~~at all~~ ~~at all~~  
 we can to ~~we~~ color  
 a pot them ~~some~~  
 und are feet ~~are~~  
 hand frozen are ~~are~~  
 crabs ing. lo ning are for  
 a man is hot for haws

362

In the second section, **Reading Processes of Dyslexics**, we will report an experiment that examined in detail the reading and spelling of five adult dyslexics who were successful college students. We will argue that their reading problems can be localized to word encoding and that they have failed to master the symbol sound relations that underlie English orthography.

In the third section, **Theories about the Underlying Deficit**, we will evaluate four theoretical proposals that attribute dyslexia to a deficit in a particular cognitive or perceptual process. Although the evidence is mixed, we conclude in favor of the proposal that the deficit is related to the retrieval of verbal codes.

In the fourth section, we will discuss **Correlated Characteristics of Dyslexia**, both characteristics that suggest a hereditary component to dyslexia and those that suggest environmental influences. The strong evidence of sex differences in the incidence of dyslexia suggests that a hereditary factor is involved in at least some types. In addition, survey studies suggest that environmental factors such as the socioeconomic background of the child and the nature of his schooling also play a role in dyslexia.

In the final section, **Acquired Dyslexia**, we will discuss studies of adults who lose some aspect of their ability to read as a result of physical damage to their brain caused by a stroke or head trauma. Recent studies of acquired dyslexics have revealed some of the neurological underpinnings of reading skill. We will compare the reading of such acquired dyslexics to that of dyslexics who fail to learn to read normally in the first place.

## Who is Dyslexic?

The term **dyslexia** literally means "faulty reading." However, it is intended to designate a much more specific syndrome: reading that is markedly below what is expected, based on a person's intelligence. This discrepancy between reading performance and IQ distinguishes dyslexia from **poor reading**, in which a person's poor reading performance is consistent with other measures of general intellectual ability. Throughout this chapter, we will use the terms *dyslexics* and *poor readers* to contrast these two groups of people. In addition to this theoretical distinction, researchers have also implicitly defined dyslexia by deciding which readers to include in their experiments. In this section, we will consider how the selection criteria constitute an answer to the question Who is dyslexic? and, equally important, how the criteria have influenced the resulting theories of this disorder.

### Definitions of Dyslexia

Two main approaches have been used in defining dyslexia: (1) the exclusionary approach and (2) the inclusionary approach.

The **exclusionary approach** classifies as dyslexic a person who has severe reading problems in spite of sufficient intelligence and for whom there is no other obvious noncognitive explanation for the problem (Critchley & Critchley, 1978). The term *exclusionary* refers to the exclusion "of people who have characteristics that could contribute to poor reading: low IQ, poor schooling, hearing or visual problems,

neurological damage, or emotional problems. The people selected by the exclusionary approach certainly constitute the most compelling cases of dyslexia—average or bright students, who for no fathomable reason, read atrociously.

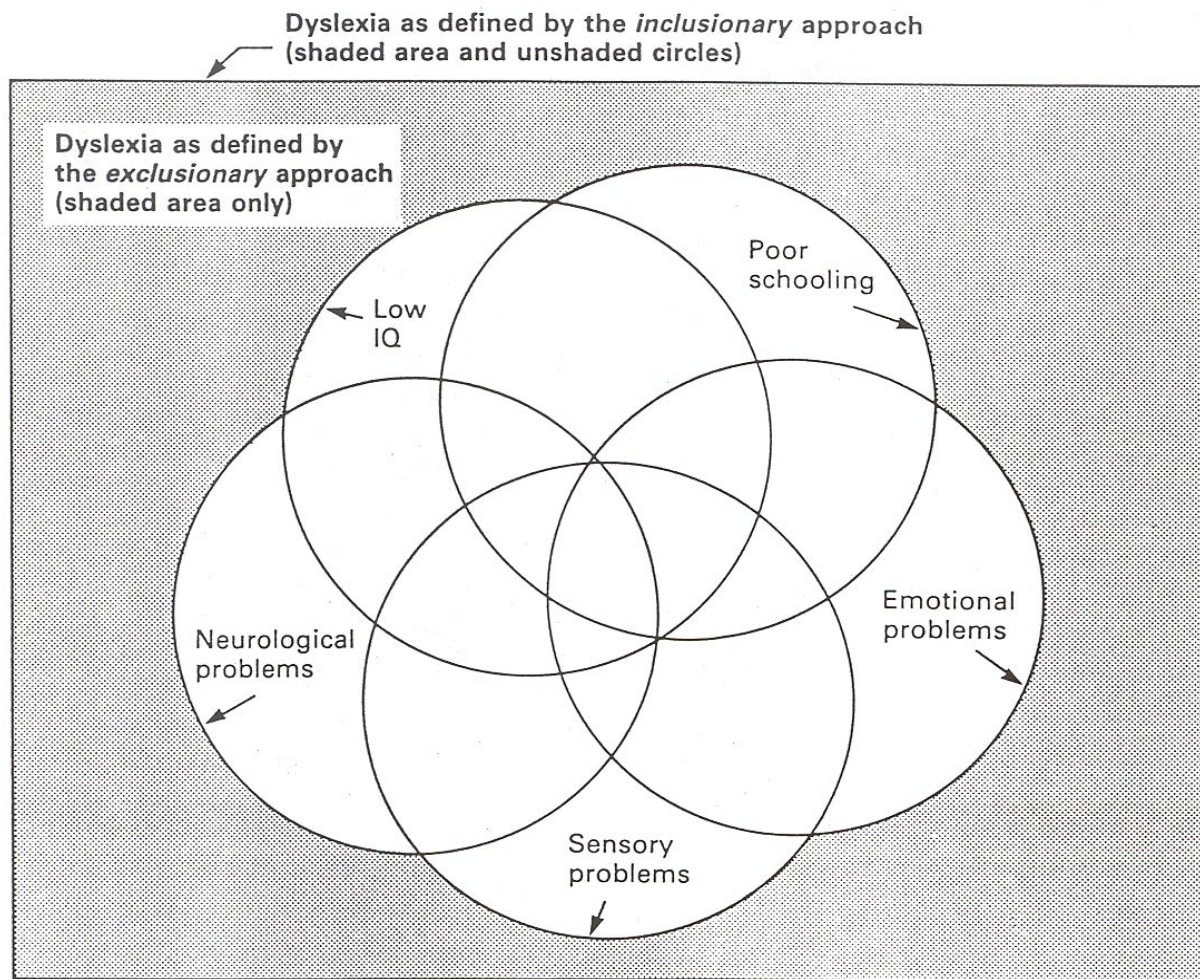
Most researchers who use the exclusionary definition assume that dyslexia can also occur in people who do not fit the exclusionary criteria, that is, they assume that dyslexia can also occur in people who have a low IQ, poor school attendance, neurological problems, or emotional difficulties. The decision of who to study and who to exclude reflects a research strategy. It is an attempt to select for study a sample of children or adults who are more likely to have similar problems (Eisenberg, 1978). For example, some poor readers who attend school sporadically may be dyslexic; on the other hand, others of them might have been able to read normally if their schooling had been more regular. The requirement that schooling be normal is an attempt to exclude those poor readers who would have otherwise learned to read and thereby obtain data that are more systematic and amenable to a theoretical explanation.

Similarly, the lower bound on the IQ score is an attempt to select a more homogeneous sample. Critchley and Critchley (1978) pointed out that low levels of decoding skill can be achieved by children with an IQ as low as 60 (the average IQ is 100). But children who have IQs between 60 and 90 often have a host of learning-related difficulties. Consequently, it is difficult to identify among low-IQ children those who have a specific reading difficulty and those who have a more general intellectual impairment. By excluding from study those poor readers with IQs lower than 90, researchers try to select readers who all have problems that are specific to reading.

An undesirable outcome of the exclusionary approach is that it may produce a sample of people that is not representative of most dyslexics (Benton, 1978). Dyslexics may typically have one or more of these complicating characteristics. Thus, the exclusionary approach produces a more homogeneous sample of dyslexics, but it may be an atypical sample.

A different approach to dyslexia, the **inclusionary approach**, defines as dyslexic anyone who is reading markedly below their expected level, even if they display other characteristics such as low IQ, poor schooling, emotional difficulties, and so on. One proponent of the inclusionary approach, Rutter, advocates studying readers with these characteristics so that the contribution of these factors to severe reading problems can be evaluated empirically (Rutter, 1978). Rutter defines dyslexia as a severe reading impairment (which he calls *specific reading retardation*).

Rutter and his associates studied the incidence and correlates of severe reading problems in various large populations, such as the entire population of 10-year-olds on the Isle of Wight and a large sample from inner London (Rutter & Yule, 1973). Each subject's IQ score was used to calculate what level of reading attainment could be expected from him. A comparison between the expected level and the actual reading score was used to identify children who read far below expectation. This procedure allowed low-IQ children to be included in the sample. In fact, most of the children who would typically be excluded by the exclusionary approach were included in this approach. It was found that the incidence of specific severe reading problems was correlated with environmental factors, such as the quality of the schooling and family size, as well as personality factors, such as impulsiveness and restlessness. This research



**Figure 12.2** A Venn diagram illustrating the characteristics of dyslexic readers. The exclusionary approach selects readers with severe reading problems who do not have identifiable characteristics such as low IQ, poor schooling, visual or auditory problems, and so on. These would be represented by people who are not in any of the circles. The inclusionary approach selects readers with severe reading problems irrespective of the presence or absence of other concomitant problems such as poor schooling or a low IQ. Thus, this approach would select readers from either inside or outside of these circles. Clearly, the two approaches may select somewhat different samples of dyslexics.

approach has significantly influenced Rutter's theory of dyslexia. He argued that dyslexia results from some basic problem that leaves the child at risk for reading difficulties. But whether the risk translates into dyslexia depends on these other environmental factors, such as the quality of schooling, the family characteristics, and the reader's personality characteristics.

**Comparison of approaches** It is no surprise that the inclusionary approach is likely to lead to a model that proposes multiple causes or types of dyslexia. Because this research admits complex cases, it ends up with a complex theoretical account. By contrast, the

exclusionary approach simply excludes from study those readers with other problems. Children who fit the exclusionary definition of dyslexia would presumably constitute one subset of children identified through the inclusionary approach, as illustrated in Figure 12.2. The difference between these two approaches may explain some of the inconsistencies in the research literature on dyslexia. The results of studies that use one population may differ from those that use another.

Each approach is useful for different purposes. The inclusionary approach is useful for evaluating the influence of nonreading factors on dyslexia, for estimating the incidence of severe reading problems, and for formulating public policy, such as deciding who should receive remedial education. The exclusionary approach is useful for isolating dyslexia in a form that may be more amenable to cognitive research. After an adequate model has been formulated and the basic processes in dyslexia are understood, the exclusionary approach could be broadened to investigate how the other factors affect the basic processes. The exclusionary approach seems a necessary first step toward constructing a precise model of the psychological processes in dyslexia.

**Other approaches** Unfortunately, the inclusionary and exclusionary approaches are not the only ways in which dyslexia has been defined. For example, some researchers believe that the term *dyslexic* should be applied only to readers who remain functionally illiterate in spite of remedial instruction. For these researchers, the *phrase remediation of dyslexia* is a contradiction in terms (Zigmond, 1978). This particular approach is undesirable because the definition of a condition should be kept conceptually distinct from its possible remediation. For example, one would not want to include as part of the definition of a disease the proviso that it be incurable.

Another common research approach is to label as dyslexic children who are reading two years or more below their grade level. The major problem with this approach is that there often is no attempt to determine if the child's difficulties are specific to reading. A sample selected by this approach could include a large proportion of poor readers who are generally intellectually slow and whose problems are not specific to reading. A second problem with this approach is that a fixed time span, such as a two-year deficit, is a proportionally larger deficit for younger children than for older children. Thus, if this criterion were used to select dyslexics of different ages, there could be systematic differences in the degree of their reading difficulty.

In summary, different operational definitions of dyslexia cause different groups of subjects to be selected for study. These differences may account for some of the conflicting results and theories that characterize the research literature in this area.

## Different Types of Dyslexia

Regardless of whether dyslexia is defined by an inclusionary or exclusionary approach, it can be conceptualized as a single condition or as an umbrella term that covers several distinct reading problems (Applebee, 1971; Wiener & Cromer, 1967). Those

investigators who conceptualize dyslexia as an umbrella term have recognized the need for a typology to categorize what they consider to be different types of dyslexia. While many typologies have been proposed, several focus on a distinction between a dysfunction in a *verbal* versus a *visual* aspect of reading (Boder, 1970, 1971; Ingram, Mason, & Blackburn, 1970; Mattis, 1978; Mattis, French, & Rapin, 1975; Myklebust & Johnson, 1962). Other typologies have been based on familial versus nonfamilial patterns of reading disability or on differences in various cognitive, perceptual, or motor behaviors.

**Boder's typology** We will describe one particular typology that is based on the distinction between the verbal and visual components of reading (Boder, 1971, 1973). Our purpose is to illustrate this approach to dyslexia and to raise several theoretical questions about this particular typology, as well as about the more general approach.

Boder's typology was developed with a population of 107 children, 92 boys and 15 girls, between 8 and 16 years in age, selected from approximately 350 children referred to a school neurology clinic. The selected children fit the exclusionary definition of dyslexia: They were two or more years behind in reading, with adequate IQ (90 or above), normal hearing and vision, good health, and without gross neurological or emotional problems. The children were classified on the basis of their reading skills (particularly their sight vocabulary) and their spelling skills (particularly their ability to spell words that were in their sight vocabulary and words that required overt word-attack skills for pronunciation). On the basis of reading and spelling patterns, the children were classified into three major groups and a remaining fourth group that consisted of children who were not classifiable:

Group	Nature of the Problem	Percentage of Children
1. Dysphonetic	Phonological analysis	63
2. Dyseidetic	Visual perception and visual memory	9
3. Mixed	Both phonological analysis and visual memory	21
4. Unclassifiable		6

The most common type (63 percent) of dyslexic was the **dysphonetic**, who had difficulty learning sound-symbol correspondences. Dysphonetic readers could identify some words, but their sight vocabularies were small. What was more striking, however, was their lack of word-attack skills to pronounce words that were not in their sight vocabulary and their nonphonetic spelling of words that they could not visually identify.

Another group (9 percent), the **dyseidetics**, had difficulty memorizing word forms or, at an earlier age, had difficulty recognizing letters. These children had extremely small sight vocabularies, presumably due to their inability to remember what words look like. They spelled unknown words phonetically and, more generally, they learned and used symbol-sound correspondences to pronounce some words. However, they used word-attack skills past the point at which normal readers recognized words visually.

The third group (21 percent), described as mixed, displayed both problems and, consequently, had worse reading and spelling problems than the other groups. Like the dyseidetic dyslexics, this group had small sight vocabularies. And like the dysphonetic dyslexics, they had difficulty learning symbol-sound correspondences and lacked word-attack skills. Boder said it was difficult to distinguish these children from dysphonetic dyslexics. Both groups were very poor spellers, but the mixed group's spelling was less phonetic. For example, a 10-year-old boy in the mixed group spelled *mother* as *methen* and *kitten* as *Ilk*. While Boder gave no data on the stability of these classifications, she said that some children in the mixed group learned phonics. As a result, their patterns changed, becoming dyseidetic. Boder also commented that the long-term prognosis for the children in the mixed group was poorer than that for the other two groups. Thus, perhaps the mixed group contained children who represented more extreme cases of the problems exemplified by the first two groups.

**Evaluation of the typology** The idea of multiple types of dyslexia is intuitively appealing because reading requires so many component skills and resources that it is reasonable that one or another could be impaired, resulting in different types of disability. In spite of this intuitive appeal of dyslexia typologies, their premature use creates difficulties.

The central theoretical issue in evaluating a typology is whether the proposed differences among types of dyslexia reflect distinct disabilities or just quantitative variations of a single type of disability. Deciding between these two alternatives requires a clearly articulated model of the interrelations among reading skills. For example, to evaluate Boder's typology, one would need a clear theory of the relation between sight vocabulary and the mastery of symbol-sound relations at various levels. Boder's typology assumes that these are independent skills. However, as we proposed in Chapter 11 on beginning reading, the mastery of symbol-sound relations may contribute to the development of a sight vocabulary, thus calling the typology's assumption into question. This example illustrates that typologies are implicit forms of a theory, which must be made explicit in order to evaluate their assumptions.

A second issue in typology evaluation concerns the effect of instruction on the skills that are the basis of the classification. Could the different groups in a typology reflect different educational histories or reading strategies, rather than qualitatively different types of dyslexia (Vellutino, 1979)? This question is particularly important if the classification scheme is based on school subjects like spelling and reading, as Boder's is. For example, could Boder's dyseidetic group simply consist of children who had more phonics instruction than those in the dysphonetic group?

A third issue is the possibility that different types of dyslexia are manifestations of the same syndrome at different stages of development. Age differences, in general, merit careful attention. Older dyslexic children generally have larger sight vocabularies and are more familiar with orthographic regularities. Consequently, an older child will read differently than a younger child simply because of the skills he has acquired. The child's developmental level should be taken into account in any typology, but the importance of this factor is clearest in the typologies based on cognitive skills.

Finally, the empirical validity of the typologies has been questioned by researchers who fail to find the proposed distinct types of dyslexics (see Firth, 1972; Naidoo, 1972; Vellutino, 1979). Their failure to replicate might simply be attributed to the possibility that certain types of dyslexia are relatively rare, so that there may be a low likelihood of sampling such subjects. Alternatively, the populations used in various studies may differ systematically. For example, the kinds of dyslexics who are selected from clinical populations, such as those in Boder's study, may differ from dyslexics who are not referred to clinics. There may also be sampling differences between studies that use exclusionary and inclusionary approaches. On the other hand, instead of being due to differences in sampling, the failures to replicate could reflect the unreliability of the proposed classification.

It is unclear whether there are distinct types of dyslexia and whether such types are associated with different causes and eventual outcomes. Many of the theoretical questions raised about Boder's typology can also be raised about other proposed typologies. Thus, a reasonable position is to consider the various typologies as plausible hypotheses for which there is no strong evidence. Nevertheless, the general idea of different types of dyslexia will continue to remain intuitively appealing because reading is a complex cognitive process that seems likely to be vulnerable to more than one type of dysfunction.

### **Incidence of Dyslexia**

A study of over five thousand British children between the ages of 9 and 11 found that 3 to 6 percent could be classified as dyslexic (Yule, Rutter, Berger, & Thompson, 1974). In this classification, the researchers used the correlation between reading skill and IQ to identify those children who were reading significantly below the expected level. The researchers did not eliminate from the dyslexic category those readers with poor schooling or environmental, sensory, or neurological problems. Thus, this 3 to 6 percent estimate of the incidence of dyslexia is higher than an exclusionary definition would produce. A much lower estimate of the incidence of dyslexia was obtained by surveying studies that used the exclusionary definition of dyslexia (Benton, 1975). According to that survey, the incidence of dyslexia is about 3 percent in boys and 0.5 percent in girls, based on the results of several studies in the United States and Britain. The higher incidence in boys is a point we will return to in the section **Correlated Characteristics of Dyslexia**.

Dyslexia is much rarer than milder forms of reading difficulty. The proportion of children with some reading difficulty (defined as having reading skills significantly below expectation for their chronological and mental age) is between 10 and 30 percent by various estimates (Benton, 1975).

The incidence of dyslexia is more than just the bottom of the distribution of reading ability. It might be expected that reading skill, like many cognitive skills and physical traits in a population, would follow a normal distribution. For example, along the distribution of heights, there are a small number of extremely tall people at the top of the distribution and a similar number of very short people at the bottom of the distribution; most people's height lies within one standard deviation of the population average. However, the distribution of reading skills differs from that for heights; there are more readers at the very bottom than one would expect in a normal distribution. In eight

large-scale studies, the incidence of dyslexia (defined as reading at least 30 months below what would be predicted on the basis of age and IQ) was greater than if reading skill were simply normally distributed like a physical trait, such as height (Rutter & Yule, 1975). This finding suggests that dyslexia is a particular syndrome or set of syndromes and not just the bottom of a normal distribution of skill levels.

## Reading Processes of Dyslexics

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Comparing the reading of dyslexics to that of normal readers can provide powerful clues about the nature of dyslexia. To characterize normal readers, we have described studies that examined their eye fixations during reading, their level of comprehension, and other task performance (Just & Carpenter, 1980). To obtain a comparable characterization of dyslexic readers, the reading skills of five dyslexic college students were compared to those of normal college students in a series of experiments (Carpenter, Just, & McDonald, 1984). In this section of the chapter, we will describe our study of reading by dyslexic college students.

The dyslexics (four men and one woman) had been diagnosed in reading clinics and fit the exclusionary definition of dyslexia; in spite of being above average in IQ, they had marked difficulties in reading. There was no obvious educational, neurological, emotional, or physical explanation of their problems. The dyslexics were recruited through university-level reading clinics and informal contacts in the Pittsburgh area. In addition to the usual exclusionary criteria, we added the stipulation that their overall academic performance in college or university be at least passable. The control group consisted of nine normal college students.

In the main study, the dyslexics were asked to read a variety of articles, either aloud or silently, while their eye fixations were recorded. After they read a passage, they briefly summarized what they had read and then they answered a number of short-answer questions about the passage. The articles varied from 500 words to about 1,000 words in length. Some were on scientific and technical topics and had been excerpted from *Scientific American*, while others were nontechnical and had been excerpted from *Reader's Digest*.

In addition to the study of actual reading, a number of additional experimental tasks examined other cognitive skills. One such task was a spelling test. Other experiments tapped visual skills, such as visual matching and mental rotation. These other experiments will be described in later sections of the chapter.

## Reading Errors and Eye Fixations

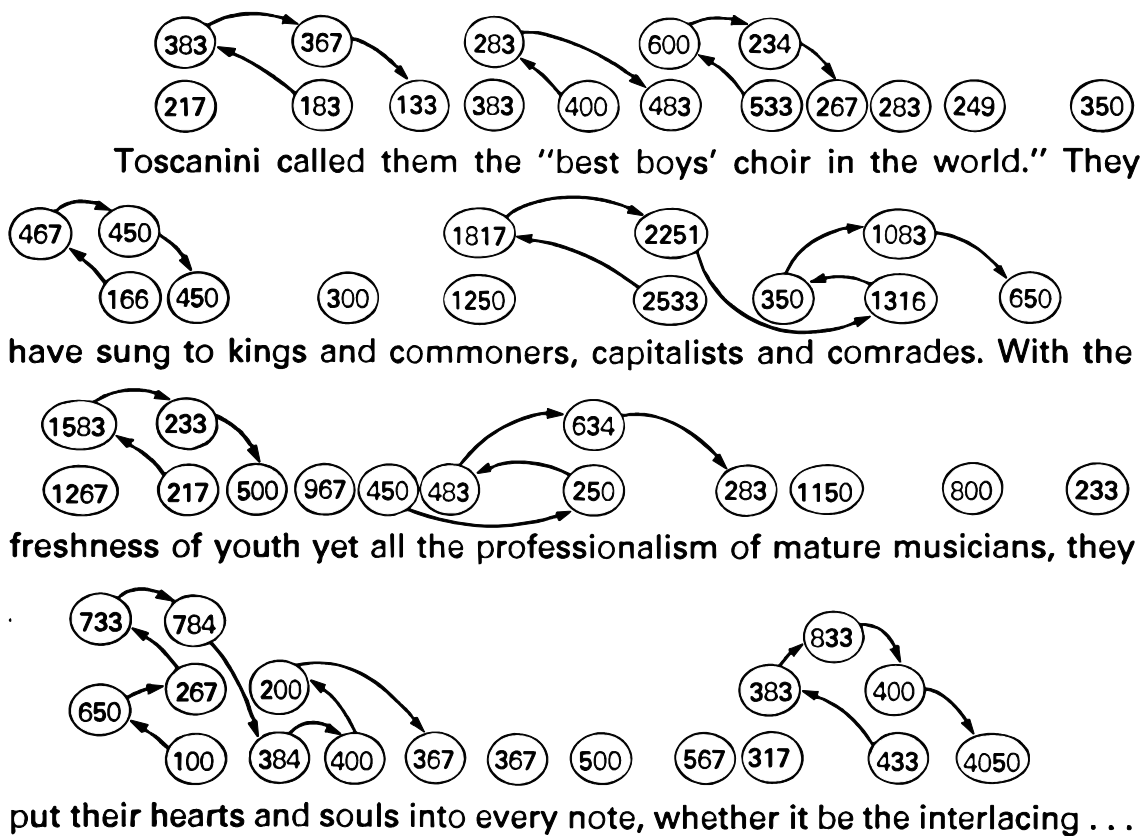
**Oral reading** As soon as the dyslexics began reading aloud, it was apparent that they were not normal college readers. The dyslexics read much more slowly and with little intonation or expression. They made many more pronunciation errors. They also answered fewer comprehension questions correctly at the end of each passage, approximately 45 percent compared to approximately 60 percent for the normal readers. Moreover, the dyslexics read at 76 words per minute on average, which was half the speed of the normal college readers (154 words per minute). Thus, the dyslexics' problems were evident from a variety of measures.

(no response)  
Toscanini called them the "best boys' choir in the world." They  
*sang* *commadors . . . I don't know*  
 have sung to kings and commoners, capitalists and comrades. With the  
*young*  
 freshness of youth yet all the professionalism of mature musicians, they  
*hands* *where it be where it be the inter . . .*  
 put their hearts and souls into every note, whether it be the interlacing  
*harmonics* *Gos . . . I don't know* *they infarences of*  
harmonies of a Gastoldi madrigal or the infectious three-quarter-time of  
*Scores*  
 a Strauss waltz.  
*Through the performance, through the performer*  
Though the performers are young—from 10 to 14—their choir is  
*18, 1498 where Hangsinvar . . .*  
 ancient. It was formed in 1498, when Hapsburg Emperor Maximillian I  
*the . . . I don't know*  
 collected a group of eight boys to sing in his chapel, the Hopburgkapelle,  
*Virginia's imprissit imperial*  
 in the heart of Vienna's imperial palace.

**Figure 12.3** An excerpt illustrating the typical mispronunciations of a dyslexic who was reading aloud from a *Reader's Digest* article. The regular type is the text; the underlined words are those that were mispronounced or skipped; written in italics above the text are the dyslexic's mispronunciations or comments. The words that are not underlined were pronounced correctly.

A more detailed analysis of the dyslexics' oral reading gives a better indication of their reading problems. The problems seem to reside at the level of word encoding. For example, Figure 12.3 illustrates the mistakes made by one dyslexic, which were typical of the mistakes of all five readers. The figure contains an excerpt from a *Reader's Digest* article about the travels of the Vienna Boys' Choir. This part of the article had been preceded by several other paragraphs that described the illustrious history of the choir, so the reader had been presented with a rich context. In spite of his general familiarity with the topic, this dyslexic made several errors. The words that are underlined are ones that he mispronounced, skipped, or for which he substituted a different word; his mistakes are written above the text. For clarity, the correctly pronounced words have not been written above the text.

As the figure makes clear, this dyslexic had difficulties that were not experienced by other university students. His difficulties are even more striking given that this individual was very bright. He was a college senior, with a B grade-point average, majoring in engineering at a prominent university. Still, he not only made many errors, but he also could not pronounce some words that other university students recognized on



**Figure 12.4** The sequence of gazes on the text while the dyslexic was reading aloud. The numbers in the circles are the duration of the gaze (in milliseconds). The gazes were forward through the text, unless an arrow indicates the direction to and back from a regressive gaze to earlier words. As the figure illustrates, the dyslexics had extremely large average gaze durations and made a large number of regressive fixations.

sight. He had the most difficulty with proper names. For example, he read *Vienna's* as "Virginia's," *Gastoldi* as "Gos," and *Hapsburg* as "Hangisvar." Presumably, proper names are difficult to decode because they occur infrequently and some may be entirely unfamiliar.

Not only were the word-encoding problems evident in the dyslexics' mispronunciations, but they were also evident in the patterns of eye fixations. The dyslexics had large average gaze durations and, unlike normal readers, made many regressive eye fixations. To illustrate these characteristics, Figure 12.4 shows the sequence of gazes made by the dyslexic while he was orally reading the text shown in Figure 12.3. This reader fixated more words than a normal reader, the durations of the gazes were much longer than normal, and he spent a very long time on the words he pronounced incorrectly. For example, he spent over 10 seconds on the phrase *commoners, capitalists and comrades*, over 2.5 seconds on *young*, and over 4 seconds on the phrase the *Hopburgkapelle*.

These same features characterized the eye fixations of all five dyslexics. They all spent a long time on words the first time they looked at them, made many regressions

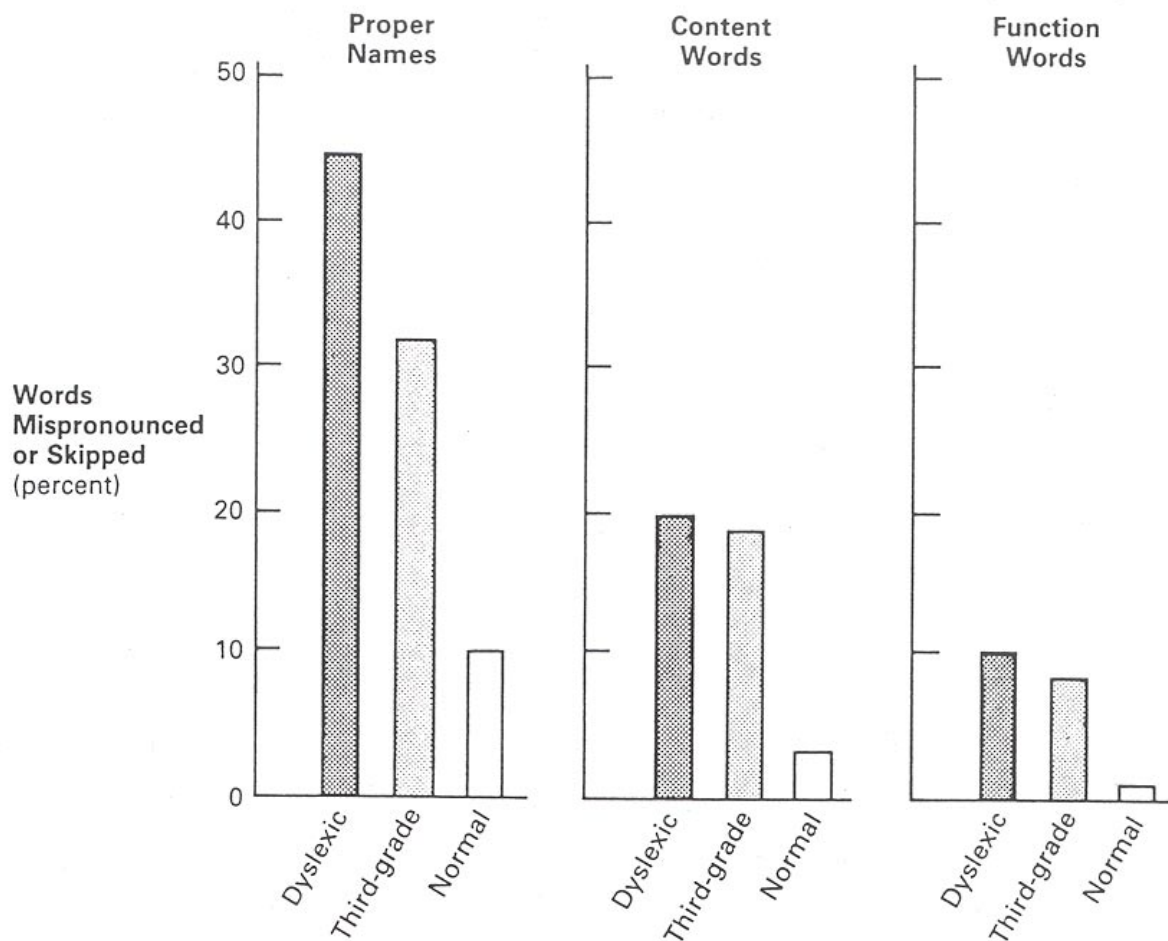
to previously fixated words, and spent an inordinately long time on words that they ultimately mispronounced. On average, the dyslexics spent an average of 1,663 milliseconds fixating a content word that was mispronounced and 2,529 milliseconds on a proper name that was mispronounced. By contrast, a normal reader can orally read a six-word sentence in about 2,500 milliseconds. Although the dyslexics' difficulties were quite evident in the pattern of eye fixations, unusual eye fixations are not the cause of the reading problems; the numerous regressions and long fixations are a reflection of the dyslexics' problems in recognizing words and understanding the text.

The pronunciation errors of the five dyslexics were quantitatively and qualitatively different from those made by the normal college students reading the same texts. Overall, the dyslexics made five times as many oral-reading errors as the normal college students. A response was classified as an error if the reader skipped, substituted, or mispronounced a word. The dyslexics had the most difficulty with proper names (like *Gastoldi*). The most common error was to mispronounce a proper name or to misread one word as another visually similar one. The errors could frequently be localized to a particular part of a word, typically the middle or end. The dyslexics usually pronounced the first letter or first syllable correctly. This pattern was apparent in the errors in Figure 12.3. For example, *youth* was pronounced as "young" and *Budapest*, as "Bomaress." The dyslexic readers may have encoded only the beginnings and sometimes the endings of long words. By contrast, when the normal readers made errors, they produced a response that was much more similar to the correct word. Moreover, normal readers never gave up trying to pronounce a word, as dyslexics sometimes did.

In some ways, the dyslexics' oral reading resembled that of much younger readers. A group of 12 third-graders orally read the passages at a similar overall rate (60 words per minute) as the dyslexics (76 words per minute) and with as little inflection. As Figure 12.5 shows, the third-graders also made a similar number of oral-reading errors. The figure shows how both the third-graders and dyslexics made the most errors on proper names. Also, like the errors that dyslexics made, the third-graders' mispronunciations and substitutions were more similar to the first part of the actual word than to the other parts.

In spite of the similarity in overall word-encoding skill, there were important differences between the third-graders and dyslexics. The third-graders' problems were not due as much to a lack of decoding skill as to a lack of familiarity with the topics and words. The passages would have been difficult for the third-graders even if they had heard them rather than read them. Not surprisingly, the third-graders were unable to answer the comprehension questions. By contrast, although the dyslexics had difficulty encoding words, they possessed more general knowledge, which partially compensated for their poor word-encoding skills. Thus, even though the third-graders' reading rate and level of pronunciation errors were comparable to those of the dyslexics, the difficulties experienced by the two groups arose from very different sources.

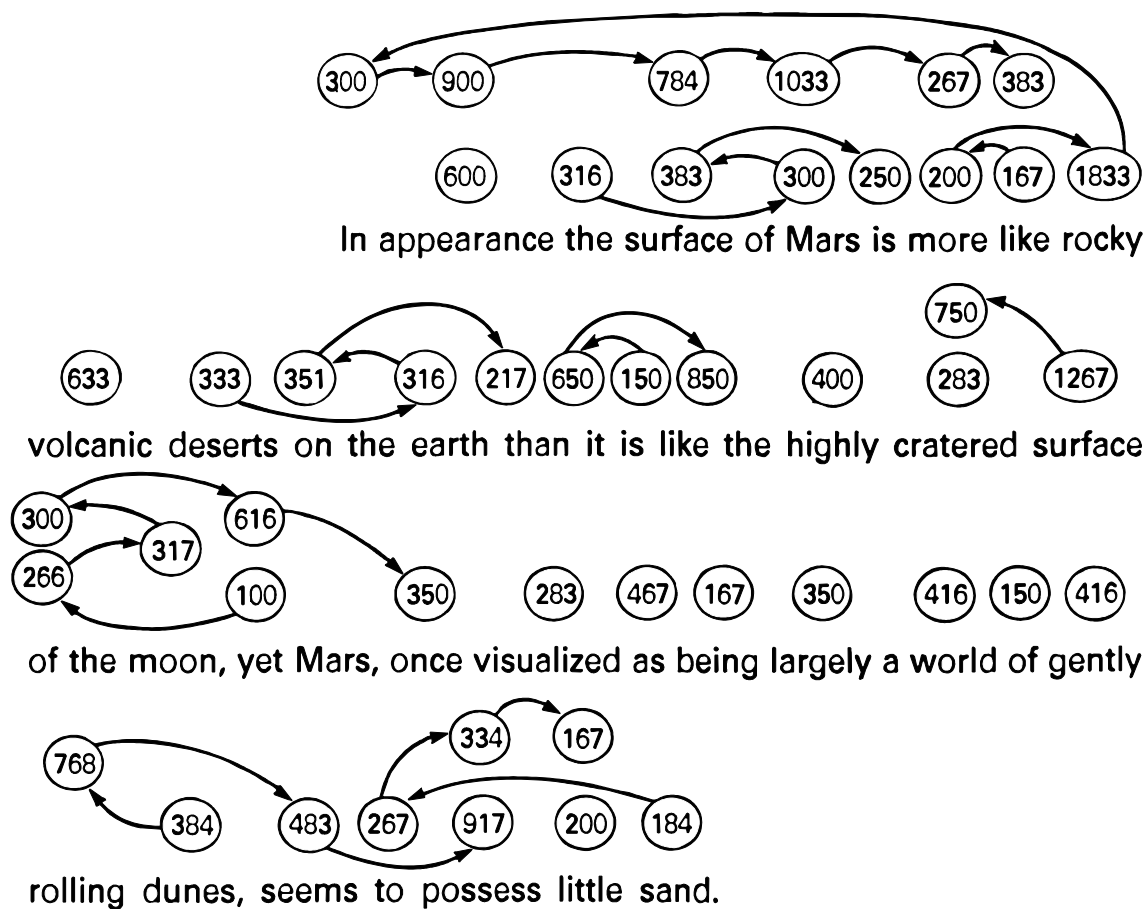
**Silent reading** Our study also examined the silent reading of these dyslexic college students. Figure 12.6 shows a typical eye-fixation protocol, illustrating the dyslexics' slow, effortful reading. On average, the total gaze duration was around 460 milliseconds per word, that is, almost half a second per word. By contrast, normal college readers



**Figure 12.5** The percentage of words that were mispronounced or skipped during oral reading for three groups of readers: dyslexic college students, third-graders, and normal college students. The three panels show the percentages separately for three types of words: names (like *Strauss*), other content words (nouns, verbs, adjectives, and adverbs), and function words (such as prepositions, conjunctions, and determiners).

in this experiment and in other research averaged about half that long on a word.

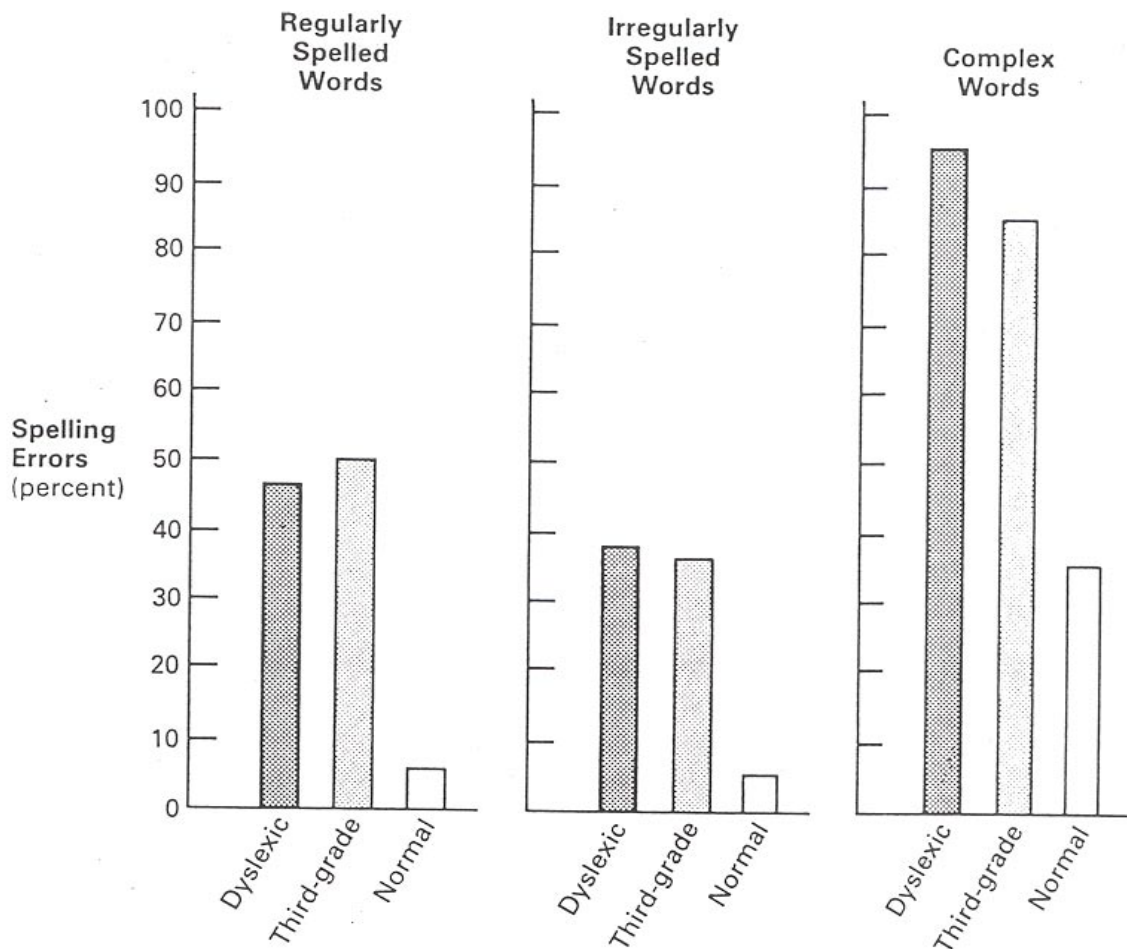
In both normal and dyslexic readers, long and less frequent words produced an increase in gaze duration. However, the increase was larger for the dyslexics than the normal readers. By contrast, dyslexics spent much less time at the ends of sentences than normal readers. Also, the way that dyslexics treated new words depended on whether they were part of an easy or difficult text. When reading an easy passage, most of the dyslexics gave up on a new word relatively quickly, perhaps because they believed the rest of the context would help them understand the gist of the passage. When reading a much more difficult, technical passage, most of the dyslexics spent a long time on new words, presumably because the context was less useful for inferring their meaning. Finally, the dyslexics' scores on the question-answering comprehension tests were about 20 percent lower than those of the normal college readers.



**Figure 12.6** The sequence of gazes on the text while the dyslexic was reading silently. The numbers in the circles are the durations of gazes (in milliseconds). The arrows indicate regressions to earlier parts of the text. This reader read the first part of the sentence twice and then continued to make more and longer gazes than a normal reader.

**Word encoding** The data from these experiments on oral and silent reading, along with other studies we will describe, suggest that the dyslexics' problems are primarily at the level of word encoding. The dyslexics have not mastered the context-sensitive symbol-sound relations that characterize English orthography. While they could generate the most common sounds associated with English letters, they lacked the word-attack skills necessary to decode fairly unfamiliar words, such as *Budapest*. The dyslexics had great difficulty visually segmenting words into units corresponding to letter clusters, syllables, and morphemes and retrieving their sounds. Of course, these dyslexics do visually recognize words. They were able to visually encode and pronounce many words, particularly more familiar words. However, they required much more time than did normal readers and they made more errors. In sum, in spite of years of remediation, these dyslexics never became fluent at encoding words.

The dyslexics also obtained less information from the texts they read. They were significantly worse than the normal readers in answering comprehension questions. However, their comprehension deficit may be attributable to their poor word-encoding



**Figure 12.7** The percentage of spelling errors made by three groups of readers: dyslexic college students, third-graders, and normal college students. The three panels show the percentages separately for three types of words: regularly spelled words (like *counter*), irregularly spelled words (like *country*), and complex words with multiple morphemes and doubled consonants (such as *accommodation*). As the figure illustrates, dyslexics and third-graders made many more errors than normal college students for all three types of words.

skill. The dyslexics were not poor at listening comprehension. Their deficits were relatively specific to reading.

**Spelling** Because dyslexics have difficulty acquiring the relations between symbols and sounds that underlie English orthography, it is not surprising that they also have difficulty in spelling. It has been anecdotally observed that spelling skills often improve less than reading skills as a dyslexic progresses through school (Critchley & Critchley, 1978).

To examine the spelling skills of the five dyslexics, a 70-word spelling test was administered. The test included several categories of words expected to elicit different levels of performance: frequent words and infrequent words, words that varied in their

orthographic regularity, words with doubled consonants and multiple morphemes, and homophones (words that sound alike but are spelled differently, like *sight*, *cite*, and *site*). Each word was pronounced and then given a sentence context that cued its meaning.

On this 70-word test, the normal college readers made an average of about seven errors; the best score was zero errors and the worst, 14 errors. By contrast, the dyslexics averaged 37 errors. The third-graders were similar to the dyslexics, averaging 38 spelling errors. Figure 12.7 presents the percentage of misspelled words for the normal college readers, the dyslexics, and the third-graders, for three categories of words that elicited some of the best and worst performance (regularly spelled, frequent words; irregularly spelled, frequent words; and complex words with double letters and multiple morphemes). Normal college students averaged about 5 percent errors for both regularly spelled, frequent words (such as *counter*) and for irregularly spelled, frequent words (such as *country*). By contrast, the dyslexics and third-graders made eight times as many errors (about 40 percent). The dyslexics performed much worse than the normal students, especially in spelling words that college students found the most difficult—words with multiple morphemes and double consonants (such as *accommodation*).

An important measure of the dyslexics' spelling skill is the phonetic acceptability of their error. A **phonetically acceptable** error is one that would sound like the target word if it were pronounced using a standard orthographic interpretation. For example, a phonetically acceptable error would be *yurned* for *yearned* or *kords* for *chords*. Phonetically acceptable errors were often generated by omitting a repeated consonant, incorrectly spelling an unstressed vowel, substituting a consonant or consonant cluster that can have the same phonemic value, or making some combination of these errors (as, for example, in spelling *cinimin* for *cinnamon*). Nonphonetic errors could differ in many ways from the target: They could omit phonemes or syllables or add extraneous ones; include letters that seldom or never take on the required phonemic value; or have no obvious resemblance to the target. Examples of the extreme nonphonetic spelling by one dyslexic included *outloul* for *pouch* and *orless* for *awkwardly*. More than half of the dyslexics' errors were phonetically unacceptable. The same was true of the third-graders. By contrast, only 15 percent of the normal students' spelling errors were phonetically unacceptable.

Most of the dyslexics' phonetically unacceptable spellings contained phonetically correct beginnings but erroneous word endings (*insures* for *insult*) or an additional or omitted middle or final phoneme (*scareces* for *scarce*). This pattern paralleled the pronunciation errors that dyslexics made in oral reading. They correctly pronounced the beginnings of words but made mistakes on the middles and ends. Both in spelling and reading, the dyslexics' errors occurred more often with less frequent words and words containing several morphemes.

The spelling results support the conclusions of the oral and silent reading studies that dyslexics have problems with tasks that require knowledge of symbol-sound relations. They are particularly slow in retrieving such information and they make significantly more errors than normal readers in both encoding words and in spelling words. In spite of the fact that these five dyslexics were all bright, successful college students, their mastery of symbol-sound relations was approximately at the level of third-graders.

These studies have focused on a small number of college-age dyslexics. In the next section, we will review studies that have analyzed younger dyslexics. These other studies also support the characterization of the dyslexics' problems as being at the level of word encoding.

### **Failure to Master Symbol-Sound Correspondences**

A number of studies have found that dyslexics lag behind their classmates in mastering context-sensitive symbol-sound correspondences. This deficit was revealed in a study that compared 36 dyslexics to 18 normal readers of the same reading levels (Snowling, 1980). The two groups had similar IQs, although the normal readers were younger, with ages ranging from 6 to 11 years, than the dyslexics, who were from 9 to 15 years old. The children were presented with pronounceable nonsense words (like *snod/sond*) that they had to judge as being the same or different. In one experimental condition, a written word like *snod* was presented first and then a short time later, a spoken word like "sond" was presented. In another experimental condition, the first word was spoken and the second was written. Thus, both experimental conditions required some internal translation between written symbols and spoken sounds, although no overt pronunciation was required. By contrast, in two control conditions, subjects were required to compare two spoken nonsense words or two written nonsense words. Thus, neither control condition required symbol-sound translation.

Compared to normal readers, dyslexics had great difficulty in the conditions that required them to translate between written symbols and sounds. Their major deficit occurred when the first nonsense syllable was written and the second was spoken, presumably because they could not accurately or quickly translate the written symbols into their corresponding pronunciation. By contrast, the dyslexics had no more difficulty than the normal readers in the two control conditions that involved two spoken words or two written words. These data support the idea that dyslexics lack facility in translating from symbols to sounds.

Firth's computer simulation (1972), described in Chapter 11 on the acquisition of decoding skill, provides further support for the hypothesis that dyslexics have difficulty with symbol-sound correspondence. Firth studied average eight-year-old readers and very poor readers who read well below what was expected on the basis of their IQ. The poor readers had problems pronouncing single isolated words and also words embedded in a text, suggesting that some aspect of word encoding was responsible for their difficulty. The task that was the hardest for the poor readers required them to pronounce nonsense words. Nonsense words cannot be recognized on the basis of a visual code; rather, they require symbol-sound translation. Firth argued that to decode unfamiliar words, children had to decompose words into syllable-size units, retrieve the pronunciations of similar syllables, and decompose and synthesize parts of the syllable. Poor readers failed to master these symbol-sound relations.

The research described in this chapter suggests that dyslexics' reading problems are at the level of word encoding (Firth, 1972; Vellutino, 1979). Failure to master the symbol-sound relations makes it extremely difficult to pronounce an unfamiliar word and may also impede the acquisition of a sight vocabulary used to encode frequently encountered words. In sum, word encoding appears to be the locus of reading problems

for many dyslexics, both young children and adults, such as the college students described earlier in this section..

Up to this point, we have described the dyslexics' problems as focused on word encoding and, moreover, as specific to reading. An alternative possibility is that word-encoding difficulties are one manifestation of a more general problem that might be apparent in nonreading tasks, as well. Next, we will evaluate several hypotheses that attribute the dyslexic's word-encoding problems to a more general deficit.

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## **Theories about the Underlying Deficit**

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In this section, we will describe four proposals that differ in their characterization of a more general deficit that may cause the dyslexic's reading problems. They attribute dyslexia to:

1. verbal coding;
2. a general language problem;
3. problems in learning and memory; and
4. visual deficits.

None of these proposals has overwhelming and clearcut support. Some studies find supporting evidence, while others are inconclusive or negative. At this point, no firm conclusions can be drawn either about the likelihood that there is a general deficit underlying dyslexia or its specific nature. Nevertheless, some of these proposals are currently more plausible than others. For example, the first proposal, that there is a general problem related to verbal coding, is one that is currently receiving a great deal of investigation. By contrast, the fourth proposal, that dyslexia is due to visual problems, has been extensively investigated in the past without obtaining clear support.

### **Verbal Coding Deficits**

The first proposal is that dyslexics have some deficiency either in identifying, coding, or retrieving verbal codes. The idea is that even though dyslexia manifests itself in reading, its origins can be traced to the verbal component of reading acquisition. The two versions of this proposal we will describe differ in their characterization of the particular locus of the problem.

**Phonemic segmentation** The ability to segment a spoken word into phonemes is needed in order to relate sounds to symbols and, consequently, to master English orthography. It is possible that severe reading problems result from difficulty in segmenting speech into phonemes. (See Gleitman & Rozin [1973] and Liberman & Shankweiler [1979] for related versions of this proposal.) As described in Chapter 11 on the acquisition of decoding skill, there is considerable evidence that poor readers often lack this skill. Such a lack would impair the acquisition of decoding skill, which depends, in part, on mapping symbols onto phonemes. Moreover, training in phonemic segmentation has been shown to improve early reading (Golinkoff, 1978). Because of such studies, it appears plausible that an inability to segment speech into phonemes may underlie reading problems and

perhaps be responsible for dyslexia.

In spite of the supporting evidence, there are at least two reasons to be cautious in assigning phonemic segmentation a central role in dyslexia. First, many of the studies that have examined phonemic segmentation have not specifically studied children who have been diagnosed as dyslexic, as distinct from generally poor readers. Thus, while difficulty with phonemic segmentation may contribute to poor reading skill, it is not clear that it is a causal factor in the specific problem of the dyslexic. Second, phonemic segmentation skills develop with reading skill (Morais, Cary, & Alegria, & Bertelson, 1979). Thus, even if the dyslexics were shown to lack this skill, their lack could be the result rather than the cause of not learning to read. While the data are suggestive, it has not yet been convincingly demonstrated that phonemic segmentation contributes to dyslexia.

**Slow verbal retrieval** Rather than a deficit that is specific to phonemic codes, an alternative hypothesis is that dyslexics, like poor readers, are generally slow and errorful in retrieving and keeping track of many different types of verbal codes. The verbal codes are internal representations of linguistic units such as phonemes, syllables, morphemes, and words. These verbal codes are not dependent on articulation because dyslexics show deficits even when no overt pronunciation is required. Such retrieval difficulties would interfere with learning to encode words because the dyslexic would be slower and less accurate in retrieving the code that is used to initially learn to read. Moreover, difficulty in retrieving verbal codes could create a bottleneck that would effectively decrease working-memory capacity both in reading and in other demanding tasks that involve such codes. A version of this hypothesis was originally formulated to explain general poor reading (Hunt, 1978; Perfetti, 1983). However, in a more extreme form, it may generalize to dyslexia.

Consistent with this hypothesis, dyslexics often have deficits compared to normal readers when they must retrieve a verbal code, whether the code is a letter's name or the pronunciation of a word or digit. This point was examined in several experiments with the five dyslexic college students whose reading was described at the beginning of the chapter (Carpenter, Just, & McDonald, 1984). One task that required retrieving verbal codes was a letter-matching task devised by Posner (Posner, Boies, Eicheiman, & Taylor, 1969; Posner & Mitchell, 1967). Subjects were timed while they decided if two visually presented letters (like A-A, A-a, or A-e) had the same letter name. If the two letters were physically identical, such as A-A, a subject could make the judgment on the basis of their visual identity. In this condition, both dyslexics and normal readers were relatively fast and their response times were indistinguishable. By contrast, when the letters were not physically identical, such as A-a, subjects could make the judgment only by retrieving verbal codes (the letter names). In this condition, dyslexics took much longer than normal readers. The additional time presumably reflects their difficulty in retrieving a verbal code.

Dyslexics also performed more poorly than normal readers in a task that required retrieving digit names, showing that their deficit is not specific to letters or words. One such task was a matching task in which subjects were required to compare two simultaneously presented strings of digits, such as 79413—79613, and judge if they were the same or different. Both dyslexics and normal readers reported that they recoded the

first string into the digits' names and rehearsed the names while matching them sequentially against the digits in the second string. Dyslexics took much longer than normal readers and made significantly more errors in this task, even though the verbal labels to be retrieved were the digit names, not letter or word names. In sum, dyslexics did appear to have a specific difficulty whenever the task required retrieving a verbal code, even though no overt pronunciation was involved.

Another finding has suggested that dyslexics may also take longer to retrieve the names of depicted objects. Denckla and Rudel (1976) compared approximately 50 dyslexics with approximately 50 nondyslexic, learning-impaired children and 120 normal children. Across all ages (7 to 12) and four kinds of materials (colors, numbers, letters, and pictures of objects), the dyslexic children took longer to generate names than the nondyslexic children with learning disabilities, and both groups took longer than the normal readers. Denckla and Rudel argued that the dyslexics' slowness was not some general slowness in perceptual motor reaction time. Their argument was based on the indirect evidence that the dyslexics were generally faster than the learning-impaired children on timed tests, such as timed IQ tests. The results support the proposal that slowness in verbal retrieval is not specific to retrieving sounds associated with letters but is a general problem that exists for several types of verbal codes.

Most of the tasks that have revealed difficulties in the time to retrieve a verbal code have used a visual stimulus, whether a letter, digit, or picture of an object. Dyslexics may have a problem that is specific to the association between visual and verbal material. Alternatively, dyslexics may have a general problem in retrieving verbal codes in response to nonvisual stimuli, as well, such as auditory or tactile stimuli.

Slowness in retrieving verbal codes might put the dyslexic at a disadvantage in working-memory tasks that involve verbal codes (Jorm, 1983). Studies of dyslexics have found that their working-memory capacity is correlated with the time they take to retrieve verbal codes (Spring & Capps, 1974; Torgeson & Houck, 1980). For example, in one study, working-memory capacity was measured using a digit-span task in which the child's span was the number of digits he could repeat after a rapid presentation (Torgeson & Houck, 1980). The child's digit span was found to be correlated with his speed in naming individual digits, which was a measure of the child's speed in retrieving verbal codes. The correlation suggests that slow verbal retrieval reduced the child's ability to retain and rehearse the verbal labels and, consequently, resulted in poor memory performance. This deficit may not characterize all dyslexics because not all of the dyslexics in this study had small digit spans. Nevertheless, the study demonstrates that slowness in retrieving verbal codes is associated with poor performance in working memory.

### **General Language Deficit**

Some investigators have proposed that dyslexia results from general language impairment at a level beyond the processes of segmenting phonemes or retrieving verbal codes (see Vellutino, 1979). One type of evidence for some general language impairment comes from studies that followed the reading progress of children whose oral language development was delayed (Rutter, 1978). Two years after starting school, one-third of the

children who had earlier experienced articulatory problems or whose language acquisition had been delayed were significantly behind in reading and spelling. By contrast, only one of twenty children in the control condition was behind. Moreover, early language problems were more closely associated with later reading problems than were early visual or motor problems. In fact, children who had problems in visual perception or visuomotor coordination were no more likely than the control group to have later reading problems. These studies suggest a link between early language problems and eventual reading disability.

One difficulty with this approach is that it does not illuminate the nature of the child's earlier or later language problems. A delay in acquiring language could be due to many factors. Without some more detailed analysis of why these children were delayed in acquiring language, it is difficult to conjecture what its relation is to dyslexia.

Another type of evidence for a general language problem comes from experimental studies that assess the existence of comprehension deficits beyond those due to word encoding. One study compared older dyslexics to younger normal readers (Guthrie, 1973). The two groups were matched on IQ and on the ability to read single words. The children read through a passage that presented three alternative words at certain points, such as:

horses	had	blanket.
<i>Both flowers lifted their ears. They were heard the forest ranger's kept.</i>		
talk	some	voice.

The children were asked to circle the most appropriate alternative. The dyslexics made more errors than the normal readers, even though the two groups had been matched in the ability to read single words.

Such results are open to several interpretations. One interpretation is that dyslexics have a general language impairment at levels other than word encoding—for example, an impairment in syntactic or semantic processing, in referential processing, or the like. Alternatively, such comprehension difficulties could be a result of a history of encoding problems that impede the development of reading comprehension skills. Because dyslexics may devote more attention to word encoding and retrieval, they may not learn to properly interrelate clauses, identify the topic, or make appropriate inferences. Either explanation could account for the results of studies that demonstrate comprehension deficits in dyslexics.

A more fundamental problem with the proposal that dyslexics have a general language impairment is that at least some dyslexics do not have obvious problems in auditory language comprehension. Consequently, any proposal for a general language deficit must also explain why the deficiencies are more apparent in reading than in listening.

### General Learning Deficits

A third proposal is that dyslexics have general learning deficits that are not specific to mastering symbol-sound correspondences. Characterizations of the possible learning deficit have varied considerably. Any theory must accommodate the specificity of the dyslexics' problem. That is, dyslexics are able to master a variety of complex tasks, both

in the laboratory and in everyday life. The proposal of a general learning disability would have difficulty explaining how some dyslexics become engineers, scientists, and medical doctors, although they cannot fluently encode words.

One of the best-known proposals concerning a learning deficit was that dyslexics have problems in associating information from the visual and auditory modalities (Birch & Belmont, 1964). However, this proposal has not held up as a result of research showing that dyslexic children do not have difficulty learning to associate nonlinguistic sounds, such as coughs, with visual figures (Vellutino, Steger, Harding, & Phillips, 1975).

Generally, dyslexics do not show an inability to learn, although they do have problems if asked to learn to associate a word or nonsense word with a referent. For example, one study required learning an association between auditory and visual stimuli (Vellutino, Steger, Harding, & Phillips, 1975). The study tested 120 children, half of them dyslexics and half of them normal readers, between grades four and six. The dyslexics had no more problems than the normal readers in learning to associate familiar, simple sounds, like hums and coughs, with visual patterns. Thus, they did not display a general learning problem or even a problem associating visual information with nonspeech sounds. However, the dyslexics made twice as many errors as the normal children if they had to associate a spoken nonsense word like *pex* to a shape or to a scribblelike written form. Vellutino (1979) has convincingly argued that dyslexics are at a disadvantage if unfamiliar verbal codes are involved in the learning task but that they do not have a general learning problem.

## Visual Deficits

The reading errors of dyslexics sometimes look like visual confusions. For instance, dyslexics often confuse reversible letters, such as b and d or p and q. And they sometimes confuse the order of letters in a word—such as *was/saw*, *clam/calm*, and *loin/lion*—and write letters in a mirror-image form, such as *N* for *N* (Kaufman, 1980). Such errors have led some investigators to suggest that dyslexia is caused by a visual disorder related to orientation (Bender, 1957; Hermann, 1959; Orton, 1925, 1937). The idea that dyslexia is essentially a visual disorder is a very commonly held opinion among the general population, as well. In spite of these widely held views, as we argued in Chapter 11 on beginning decoding, such letter confusions do not necessarily indicate that dyslexia is due to a visual deficit. In fact, letter confusions may be the result of poor word-encoding skills, rather than the cause of them (Vellutino, 1979). Young children who do not have reading problems often make such errors although the frequency of the errors decreases as the child acquires reading skill.

One of the most influential theorists who argued for a visual basis of dyslexia was Orton (1925, 1937), who believed that orientation confusions between letters, particularly the mirror-image confusions, were the fundamental cause of dyslexia. Orton developed an explanation of letter reversals based on the asymmetries between the two halves of the brain. The general idea that brain asymmetries are somehow involved in reading problems is a persistent one, although the evidence concerning the nature of the involvement is mixed (Young & Ellis, 1981). But the hypothesis that a visual deficit underlies dyslexia can be evaluated independently of Orton's theory concerning its possible physiological basis.

The most direct evidence against the visual-deficit proposal is that dyslexics have no deficit in visual tasks that do not entail verbal mediation. Two reviews of the research literature on visual deficits found that in spite of some positive results, the weight of the research evidence was against the hypothesis of a visual deficit (Benton, 1962, 1975; Vellutino, 1979). Benton wrote:

My conclusion is that deficiency in visual form perception is not an important correlate of developmental dyslexia. By this I mean that, while it may be a determinant of the language disability in some cases, it is not a significant factor in the majority of cases. (1962, p. 94)

In general, most dyslexics' reading difficulties are not due to deficiencies in binocular coordination, faulty scanning, or other oculomotor deficiencies (Rourke, 1978), nor are they due to a disability in registering visual information (Morrison & Manis, 1982). However, there continue to be clinical reports of children who show basic visual disorders (Boder, 1971; Mattis, 1978; Pirozzoto & Rayner, 1979). At most, visual disorders may account for the problems of a very small proportion of dyslexics.

**Visual tasks with implicit verbal components** In this section, we will review the arguments that some so-called visual errors are the result, not the cause, of reading problems. Many apparently visual tasks permit or encourage verbal coding, which may be the source of error for the dyslexic. As an example, consider a typical visual matching task in which a child is shown a letter and asked to find an identical letter among a given set of distractor letters. Young children who have reading problems often have difficulty with this task (Calfee, 1977). However, Calfee pointed out that a child who attempts to perform the matching with a purely visual representation might have difficulty maintaining an accurate representation of the target throughout the time needed to make a sequence of comparisons to the distractors. Successful performance might depend upon retrieving, rehearsing, and comparing verbal codes for the letters—exactly the processes that would be difficult for a child with reading problems. Consequently, poor performance might appear to arise from visual processes but would actually arise from a lack of proficiency in verbal processes.

To support his analysis of the tasks, Calfee designed visual matching tasks that minimized the role of verbal coding. For example, in one version, only two figures were presented at one time to minimize the number of comparisons that were required. The figures were letterlike but not actually letters to minimize the likelihood that a verbal code would be retrieved. Under these conditions, kindergarteners and first-graders who were at risk for reading problems had no difficulty with the visual matching tasks.

The research with the five dyslexic college students whose reading performance was described in the first section of the chapter also indicates that they do not have difficulty with visual matching tasks (Carpenter, Just, & McDonald, 1984). When required to compare simple geometric shapes or more complex shapes (such as doors, faces, or small figures), the speed and accuracy of the five dyslexic readers was well within the range of the normal control group. In fact, in a variety of tests of visual processing, such as a test that required mentally rotating complex forms to decide if two figures were the same or different, the dyslexics performed as well or better than the

normal college readers. The only visual tasks that elicited less than average performance were those that were typically performed using a verbal code, consistent with Calfee's data for very young children.

Other studies support the conclusion that many dyslexics have no difficulty with tasks that draw heavily on visual abilities, as long as the task does not evoke verbal coding. For example, dyslexic children have little difficulty with simple copying tasks that do not involve words. In two studies with children between 8 and 15 years of age, dyslexic and normal readers were equally accurate in copying a sequence of geometric figures (Vellutino, Steger, & Kandel, 1972; Vellutino, Smith, Steger, & Kaman, 1975). By contrast, the dyslexics did have problems in copying words. The dyslexics had even more difficulty pronouncing the words. Because dyslexics could copy words more accurately than they could pronounce them, Vellutino argued that perceptual difficulties are unlikely to be the root of their reading problem. Thus, there is little evidence of a visual deficit as the major problem in dyslexia.

In summary, we have reviewed a number of proposals that assume some nonreading process underlies the word-encoding problems of dyslexics. These are not the only proposals in the research literature, but they are the more frequently explored ones. At the present time, the research is equivocal and no one proposal is clearly supported. However, extensive evaluation suggests that visual deficits are unlikely to be the cause of most cases of dyslexia. The proposals of a general learning deficit or a general language deficit are not as easily rejected, partly because they have not been specified or tested as thoroughly as the proposal concerning visual deficits. But either proposal will eventually have to account for the fact that a dyslexic's problems are relatively specific to reading and do not generalize to other complex learning tasks. Finally, the proposal that dyslexics are slow in retrieving verbal codes has a great deal of supporting evidence. However, this proposal has not yet been subjected to the same level of scrutiny as the visual-deficit hypothesis, and research on all of these proposals is still ongoing.

## **Prognosis and Remediation**

A variety of remedial reading programs have been developed to help dyslexics, as well as poor readers (Johnson, 1978; Naidoo, 1981). Programs that focus on language and reading are more successful than those that focus on visuomotor or visuoperceptual training (Benton, 1978; Guthrie, 1978; Jorm, 1983). However, the evaluation literature is very sketchy. Evaluations of remedial programs seldom include control groups to determine the relative effectiveness of the program or long-term follow-ups to determine whether the improvement is long lasting. Also, many studies do not distinguish dyslexics from poor readers.

The prognosis for dyslexic children is that they will make some progress in reading as they go through school, but typically, their final level of reading achievement is not very high. "if there is a typical course, it is one where reading ability slowly improves through the years of puberty and adolescence, the patient finally becoming a relatively slow reader and a very poor speller" (Benton, 1975, p. 7).

The prognosis for dyslexics may be worse than that for poor readers. One of the few longitudinal studies that assessed the reading attainment of dyslexic children

contrasted about 80 dyslexic children with 80 poor readers (Rutter & Yule, 1975). Both groups were reading about 33 months below the level of normal readers, but the poor readers had lower IQs, by about one standard deviation, and so were reading closer to the level that was expected. After about five years, the dyslexic group, in spite of their higher IQs, had made significantly less improvement in reading and spelling than the poor readers. By contrast, dyslexics made relatively more progress in arithmetic (although both groups were performing below age level). Unfortunately, it is not known whether these children received remediation and, if so, how much or what kind. Nevertheless, this study suggests that the outlook for dyslexic children can be bleaker than that for poor readers.

Although the overall prognosis appears pessimistic, scattered studies have reported that some dyslexics improve their reading skills and can attain considerable academic and professional success. One particularly optimistic report came from Rawson's (1968) review of 20 dyslexic boys who had all attended the same private school and received remedial instruction. All but 35 percent were reading close to their grade level when they left school. Moreover, most worked as professionals, including medical doctors, lawyers, research scientists, and businessmen. Clearly, dyslexia does not necessarily prevent people from learning and practicing these demanding professions. However, occupations that require proficiency in the mechanical aspects of spelling and reading, such as proofreading and dictation transcription, are undoubtedly difficult for a dyslexic to pursue successfully.

The academic performance of the five dyslexic college students whose reading skills were described earlier in the chapter reinforces these conclusions (Carpenter, Just, & McDonald, 1984). The five students reported using a variety of coping strategies that had permitted them to not only survive but even excel in their academic careers. Understandably, reading was not their favored way of mastering school material, although they could and did struggle through textbooks, assignments, and exams. They reported paying close attention to lectures and sometimes arranged for friends and parents to read course materials to them. In only one case had the reading difficulty previously caused academic problems that reflected a mixture of both cognitive and motivational difficulties. The student had not been diagnosed as dyslexic until he was in high school. Until that time, he had considered his earlier academic problems to be due to a lack of intelligence or conscientiousness. Once he was identified as dyslexic, he no longer doubted his intellectual ability. Although his reading skills continued to be extremely poor, he became academically motivated and, at the time of the experiment, he was planning to enter graduate school in biology.

Although these reports demonstrate that some dyslexics manage to attain high academic and professional goals in spite of poor reading skills, their achievements should not be construed as an argument that dyslexia is not an enormous impediment. As Benton (1975) pointed out, dyslexic children from private schools who have the help and support of parents and specialists are certainly not representative of most children with severe reading problems.

Not only do dyslexics typically have school problems, but they can experience great frustration with everyday activities, including mundane tasks such as using a telephone book or street directory, looking up a word in a dictionary, or even reading highway signs for directions (Hermann, 1959). Similarly, dyslexics may sign documents without reading or understanding them, just to avoid frustration and embarrassment. And

of course, writing and spelling, whether for personal or business reasons, continually cause error and humiliation for the dyslexic. One of the five dyslexic college students in our experiment reported relief at being able to prepare his written class assignments using a text-editing program that checked his spelling.

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## **Correlated Characteristics of Dyslexia**

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What causes dyslexia? Is it an inherited trait? Is it due to poor schooling? Or is it caused by some combination of factors, such as a basic disposition that interacts with certain schooling techniques? In this section, we will discuss some hereditary and environmental factors that are correlated with the incidence of dyslexia.

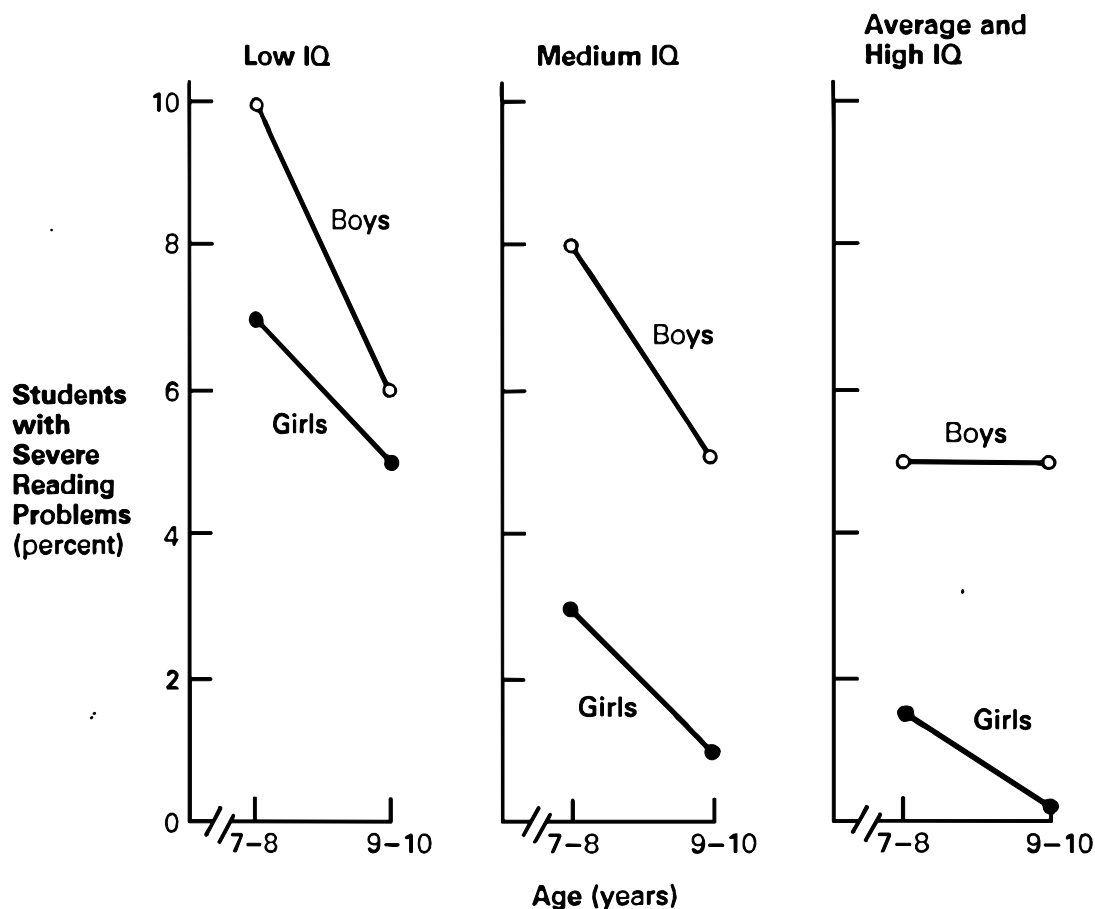
### **Hereditary Factors**

Some types of dyslexia may be biologically inherited, like baldness or color blindness. Baldness and color blindness happen to be hereditary traits that occur more often in males than females. Similarly, there may be a hereditary component to dyslexia.

**Sex differences** Many different kinds of survey studies have found that boys more frequently have reading problems than girls do. For example, a large survey of over 2,500 children in Britain found that more boys than girls were markedly poor readers and that the difference was most marked for children with average or higher IQs (Lovell, Shapton, & Warren, 1964). Presumably, the average-and high-IQ group primarily reflected reading disability due to dyslexia, whereas the low-IQ group included more children who were poor readers due to general intellectual impairment. The data, presented in Figure 12.8, also show how the proportion of children with severe reading problems decreases with age, except for boys with average and high IQs. Several smaller studies of dyslexics that used exclusionary definitions also found a much higher proportion of male than female dyslexics (Benton, 1975). This higher incidence has been interpreted by some as evidence for a biological component in dyslexia, such that males are more susceptible to this disability (as they are to color blindness and baldness).

Other researchers have suggested that sex differences may be due to cultural factors that encourage language skills in girls, including the disproportionately high number of female reading teachers and the fact that girls more often than boys are encouraged to play reading and language games (Downing, 1973; Gibson & Levin, 1975). Such cultural factors may account for part of the difference in the incidence between boys and girls; however, it seems unlikely that they could account for the greater incidence of dyslexia in boys being even greater among high-IQ children than low-IQ children. This finding suggests some role of heredity in dyslexia.

**Familial studies** If some cases of dyslexia are influenced by hereditary factors, the obvious question is whether dyslexia runs in the family. Overall, there is an impressive amount of evidence for some hereditary component in dyslexia (Benton, 1975). However, its exact nature is not clear. In particular, researchers who have tried to fit a



**Figure 12.8** The percentage of boys and girls who have severe reading problems. The three panels show the percentages for children with low IQs (less than 90), medium IQs (between 90 and 99), and average to high IQs (greater than 99). While a higher proportion of boys than girls have reading problems in each group, the difference is largest for children with IQs above 99. The data also show that the proportion of children with specific reading problems tends to decrease with age, except for the average- and high-IQ boys. *Source:* Based on data from Lovell, Shapton, & Warren, 1964, p. 58.

particular genetic model to dyslexia—for example, by assuming that it is a male-linked recessive genetic trait—have not been particularly successful in accounting for its patterns of incidence. Moreover, neither of the two major kinds of evidence for a hereditary factor is entirely conclusive nor is either likely to answer the question of the role of heredity.

One kind of study that is used to assess the role of heredity is the survey, which simply asks which other family members have reading problems. Families of dyslexics often report a higher incidence of reading problems than families of normal readers of comparable IQ and social status. However, this evidence has a potential bias, since parents of dyslexics might be more likely to report reading problems than parents of nondyslexics. In addition, the studies do not always differentiate dyslexia from generally poor reading. In fact, reading problems and language delay are reported by families of generally poor readers almost as often as by families of dyslexic readers (Rutter, 1978). Although not typically feasible, a more direct assessment of the reading skills of family

members would be a better way to determine patterns of heritability.

Another type of heritability study compares the reading skills of twins. Usually, identical twins (who are genetically similar) show more similar reading performance than fraternal twins (who are genetically no more similar than siblings). At first glance, the results of these studies are striking, and many researchers and laymen treat them as very strong evidence for the hereditary foundation of dyslexia. However, the data are not conclusive because many twin studies have not distinguished general poor reading from dyslexia. To be convincing, the twin studies should show that the problems experienced by the twins are specific to reading and not due to correlations in their general intelligence. Verbal ability, and intellectual performance, in general, has some hereditary component. But there is relatively little evidence beyond this concerning a hereditary component that might be specific to dyslexia (Rutter & Yule, 1975).

Overall, studies that indicate a higher incidence of dyslexia among boys and survey studies support a role for heredity. However, the data are not entirely conclusive. More to the point, unlike color blindness, which is solely genetically determined, dyslexia is likely to have cognitive components that influence its manifestation and remediation. Thus, it is unlikely that dyslexia will ever conform to a purely hereditary model.

**Minimal brain dysfunction** Another biologically based explanation of dyslexia is a diagnosis of **minimal brain dysfunction**. This term is sometimes applied when the reader shows no obvious evidence of brain damage, although there may be a subtle pattern of symptoms that suggests neural involvement. However, this approach generally does not provide a satisfactory explanation of dyslexia (Gibson & Levin, 1975). First, the pattern of symptoms is often so subtle that the diagnosis becomes circular. Reading or learning problems are taken as evidence of the minimal brain dysfunction, and the minimal brain dysfunction is the explanation of the reading or learning problems. Second, many dyslexics do not show signs of any neurological problems. By definition, minimal brain dysfunction cannot account for dyslexics identified using the exclusionary approach because this approach excludes children who have signs of neurological impairment. Finally, this approach has not been particularly illuminating, either in guiding remediation or in characterizing the nature and course of dyslexia.

## Environmental Factors

Although there is evidence of a possible role of heredity in dyslexia, there is also strong evidence that environmental factors are associated with the incidence of dyslexia. These factors include the socioeconomic status of the family, family size, and the characteristics of the school.

**Family characteristics** The fathers of dyslexic children are more likely than the fathers of normal readers to have jobs that are classified as manual and are less likely to have clerical or professional occupations (Rutter, Tizard, & Whitmore, 1970). Also, poor reading and dyslexia occur more frequently in families of low socioeconomic status (Rutter & Yule, 1975). One explanation is that children from low socioeconomic groups

may tend to receive poor schooling or less individualized tutoring. On the other hand, almost all environmental factors can be given an alternative interpretation that would be consistent with a heritability explanation (Jorm, 1983). For example, suppose one hypothesized that dyslexia is a male-linked inherited trait. Then the fathers of dyslexics would be more likely to be dyslexic than would the fathers of normal readers, and this might explain their greater likelihood of having manual labor occupations rather than clerical or professional occupations.

Dyslexia correlates with other factors that suggest environmental characteristics can play an important role. For example, dyslexics tend to come from large families (Rutter, Tizard, & Whitmore, 1970). Children in large families might get less individual tutoring from their parents or others if they have severe reading problems. Of course, family size is also correlated with socioeconomic status, which introduces many more possible explanations for the relation between family size and reading disability. Nevertheless, family interactions could influence the incidence of dyslexia.

**Other social factors** The incidence of dyslexia also depends on community characteristics. In the discussion of the inclusionary definition of dyslexia, we described a large correlational study by Rutter and associates that identified children who were reading markedly below what was expected on the basis of their IQs (Rutter & Yule, 1975). The study contrasted the incidence of dyslexia in both urban and rural areas of Britain and found that there was a much higher incidence (6 percent of the 10-year-olds) in inner-city London than on the Isle of Wight, a rural area (3.5 percent) (Rutter & Yule, 1975). Dyslexic children tended to come from large families whose fathers were employed in low-status jobs and from schools that had high levels of absenteeism and pupil turnover (Rutter, Yule, Quinton, Rowlands, Yule, & Berger, 1975). These factors also distinguished urban London from the largely rural Isle of Wight, since the London sample came from large families and schools with high teacher and pupil turnover. Based on data like these, Rutter argued that dyslexia is a multidetermined syndrome, a predisposition that is affected by environmental factors like schooling and family life.

**Cross-cultural incidence of dyslexia** Similar descriptions of the reading and writing problems of dyslexics have been documented in many countries, including Britain (Critchley & Critchley, 1978), Denmark, Sweden, and Norway (Hermann, 1959). The presence of dyslexia across different societies, writing systems, and educational systems suggests that none of these factors is solely responsible for dyslexia. Nevertheless, differences in the frequency of dyslexia among different countries or societies could provide evidence of possible environmental influences on dyslexia.

Cross-cultural studies are of interest from a variety of perspectives concerning possible factors that contribute to dyslexia. For example, if phonemic segmentation were the bottleneck in dyslexia, then it would be of interest to analyze the incidence of dyslexia in countries whose orthographies are syllabic or logographic, rather than alphabetic, and do not require segmentation at the level of individual phonemes. Alternatively, it has been proposed that dyslexics have difficulty learning complex rules with numerous exceptions (Morrison & Manis, 1982). It would be of interest to test this proposal by analyzing the incidence of dyslexia in languages that have more regular

alphabetic orthographies. Finally, if dyslexia were influenced by particular educational practices or social factors, then it would be of interest to analyze the incidence of dyslexia in countries and communities that differ with respect to these factors.

In spite of the desirability of such data, it has been difficult to assess the incidence of dyslexia across different countries. Moreover, as we argued in Chapter 10 on orthography, the collection and interpretation of such cross-cultural data on reading skill is fraught with problems, both in methodology and analysis. Thus far, cross-national comparisons have produced only suggestive speculations, not substantive evidence concerning the possible causes of either poor reading or dyslexia.

These studies of correlated characteristics support a role for both heredity and environmental factors in the incidence of dyslexia. But at present, the research is far from conclusive and does not specify what role each plays or how they interact in dyslexia.

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## Acquired Dyslexia

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One day, in 1895, a 58-year-old language teacher suddenly found that he could no longer read. He was still able to write words, but he could not read what he had written. He also suffered blindness in the right side of his visual field (Hinshelwood, 1917, in Geschwind, 1962). His disability was one of the first documented cases of **acquired dyslexia**, the loss of reading skills due to stroke or head injury. It has also been called **alexia and word blindness**. By contrast, the type of dyslexia that we have been describing up to this point is called **developmental dyslexia**; it applies to children and adults who fail to learn to read normally in the first place. This section describes two main types of acquired dyslexia and contrasts them with developmental dyslexia.

It has been proposed that acquired and developmental dyslexia are based on similar neurological dysfunctions and that the sites of brain damage in adult acquired dyslexia correspond to sites of abnormal development in children who cannot learn to read well. We will argue that there is no strong evidence that the two syndromes are identical.

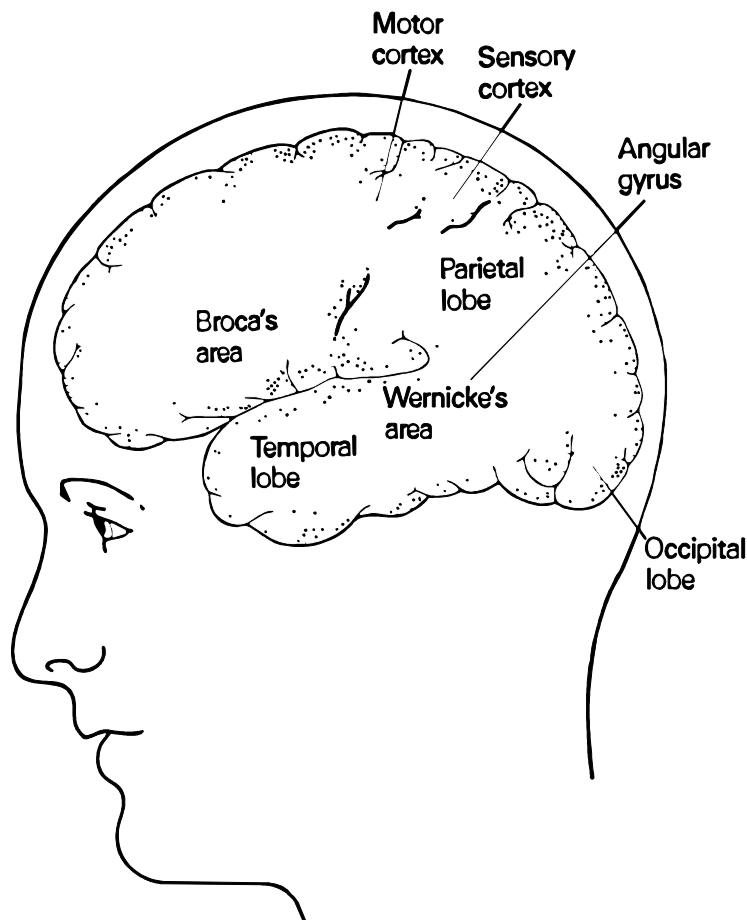
## The Neural Basis of Language and Reading

The study of acquired dyslexia has the potential of revealing important properties of reading. When some neurological trauma physically damages portions of the brain that process language, the resulting patterns of disruption in reading provide cues as to the functional relations among the component processes. Moreover, an increasing number of behavioral studies on the reading processes of acquired dyslexics are being conducted in conjunction with the use of new diagnostic imaging techniques such as PET scans. These approaches are likely to relate dysfunctions to particular brain structures.

Although all psychological processes have a neural basis, the neural basis of language has been of special interest, for many reasons (Lenneberg, 1967). One of these

reasons is that language processing is more lateralized than most other psychological processes. One cortical hemisphere does most of the language processing. In most right-handed people and at least half of all left-handed people, the majority of language processing and speech production occurs in the left cortical hemisphere. The evidence for this asymmetry between the hemispheres comes from many sources. Adult patients who have had their left hemisphere removed due to injury or illness usually have difficulty speaking, understanding, or remembering verbal information. About 95 percent of all speech disorders stemming from brain damage result from left-hemisphere damage (Geschwind, 1979). The left hemisphere can decode more words, perform more sophisticated syntactic analysis, and retain verbal information better than the right hemisphere. However, the right hemisphere does have certain language abilities. It recognizes some words and may process simple sentences describing actions or spatial and temporal relations (Zaidel, 1978).

**Localization of language function** Within the left hemisphere, different regions are particularly involved with different aspects of language: meaning, syntax and morphology, and articulation. Some of these areas are indicated in Figure 12.9,



**Figure 12.9** A sketch indicating some of the major areas in the left hemisphere. *Broca's area* is involved with syntactic processing. *Wernicke's area* is involved with semantic processing. Strokes in the area of the *angular gyrus* sometimes result in acquired dyslexia.

which shows a sketch of the left hemisphere from the left side. Most brain theories attempt to specify which brain structure performs which psychological process. In this spirit, we will describe the theories that associate brain locations with particular language-related information storage and computation. The theories are formulated by relating the specific symptoms of language pathology to the destruction of specific information processes or capacities at a particular site (Geschwind, 1979). This is called a *localist* approach. It is important to note that nonlocalist approaches focus on generalized dysfunctions. For example, Lenneberg (1967), who was not a localist, argued that some of the symptoms associated with acquired dyslexia could be interpreted as being due to general factors, such as disruption in the timing mechanisms in reading.

The three brain areas most commonly associated with language processing are Broca's area, Wernicke's area, and the angular gyrus. Many other areas (such as the areas that process visual information) are also involved in reading, but damage to these three areas is particularly associated with language pathologies. The localization of language function is relatively recent scientific knowledge. It was in the 1860s that Broca pointed out that speech disorders often resulted from damage to a particular region of the left hemisphere, an area now known as **Broca's area**. As we described in Chapter 5 on syntax, Broca's aphasics have difficulty with syntactic analysis. Their speech is slow, inarticulate, ungrammatical, and often lacks function words and syntactic markers, although it does make sense. Geschwind (1979) gave the following example of the speech of a person with Broca's aphasia who was asked about a dental appointment:

"Yes ... Monday ... Dad and Dick ... Wednesday nine o'clock ... ten o'clock ... doctors ... and ... teeth."

While such patients have difficulty speaking normally, they do not have problems with articulation since they can sing song lyrics.

**Wernicke's area**, named after the investigator who identified it in 1874, is more involved with semantic and referential processing (see Figure 12.9). Patients with Wernicke's aphasia have phonetically and grammatically reasonable speech, but the content is often nonsense. Geschwind cited the following speech sample of such a patient who was asked to explain a picture showing two boys stealing a cookie behind a woman's back:

"Mother is away here working her work to get her better, but when she's looking the two boys looking in the other part. She's working another time."

Wernicke's area also plays a role in understanding speech and in reading.

A third area, the **angular gyrus**, may be a site in which the visual form of the word is associated with the corresponding auditory pattern (Geschwind, 1979). Lesions in the angular gyrus are often accompanied by reading problems. The angular gyrus may play a role in the communication that must occur in reading between the sites that process visual information (such as the occipital lobe) and the areas that process language.

**The neurological basis of acquired dyslexia** As every clinical researcher knows, it is extremely difficult to categorize patients with brain damage on the basis of their behavioral symptoms. The symptoms are often unstable, overlapping, and masked by

other problems. Consequently, not all clinicians agree on the typology of acquired dyslexia. Nevertheless, we will focus on two main types (Benton, 1978):

1. **Pure alexia:** reading problems without writing problems or oral language problems; orally spelled words are recognized.
2. **Alexia with agraphia:** reading and writing problems and sometimes oral speech problems.

Pure alexia is striking and well understood. Alexia with agraphia is the form of acquired dyslexia that more closely resembles developmental dyslexia.

There are other types of acquired reading pathologies, as well. Some researchers have suggested a third type that entails more difficulty recognizing letters than words; in addition to having some of the symptoms above, patients of this third type cannot recognize orally spelled words. This syndrome, associated with lesions in the frontal lobe, is often accompanied by Broca's aphasia. A fourth type of reading pathology is characterized by general visual and spatial problems that interfere with reading and writing. Mattis (1978) suggested that the third and fourth types are parallel to other subtypes of developmental dyslexia, but we will not review the evidence here.

### Pure Alexia

The classic symptoms of pure alexia or *word blindness* are very much like those of the 58-year-old language teacher described earlier, who suddenly discovered that he could not read even though he could still write. The symptoms are an inability to read words or letters (although letters can be identified if their contours are traced), the ability to write dictation without being able to subsequently read what was written, and blindness for visual information to the right of the fixation point. The original neuroanatomical explanation proposed for word blindness by Dejerine is still largely accepted today (Geschwind, 1962; Goodglass & Kaplan, 1972). Word blindness results when the visual-processing area is disassociated from the language-processing areas of the brain.

Pure alexia is usually associated with a lesion in the visual cortex of the left hemisphere, which processes information from the area to the right of the point of fixation. This explains why such patients are blind to visual information that is to the right of the fixation point. Pure alexia patients also have damage to the communication pathway in the corpus callosum that carries information from the right visual cortex to the left hemisphere. Thus, although the language area of the left hemisphere is undamaged, it is isolated from visual input from either the left or right hemisphere. Consequently, these patients can understand spoken language, but they cannot linguistically process visual information.

This syndrome provides further evidence of the important role of the left hemisphere in normal reading. However, it is unlike developmental dyslexia. Pure alexia is not only rare, but it is primarily a difficulty in the visual system and communication between the visual-processing areas and the language-processing systems. By contrast, in developmental dyslexia, the problem is more intimately tied to language processing.

## Alexia with Agraphia

The second general class of acquired dyslexia is more similar to developmental dyslexia because it typically involves reading problems, as well as writing and spelling problems. Whether speech production and comprehension are normal varies considerably among these patients (Goodglass & Kaplan, 1972). The severity of the reading problems ranges from an inability to match letters or words across different type fonts, to the ability to recognize letters and sometimes short words, to slow reading with misperception of some words. Sometimes patients are unable to write individual letters from dictation, although they often can copy letters. In milder cases, they can write words but they make gross errors in spelling and lose track of the grammatical features of the word they are writing.

The brain site that is implicated in alexia with agraphia is the angular gyrus, the area that lies at the posterior margin (the rear edge) of the language area. The angular gyrus bridges the posterior regions of two main parts of the cortex, the temporal and parietal lobes. In addition, some patients with alexia with agraphia may have lesions in the parietal lobe, associated with nonlanguage problems such as difficulty in numerical calculation, finger identification, right-left discrimination, drawing, and some spatial construction tasks. Those who propose a parallel between developmental dyslexia and this form of acquired dyslexia have conjectured that developmental dyslexia is due to faulty development of the parietal area that meets the temporal and occipital areas. This area is a proposed site of convergence or association of information acquired through different sense modalities.

**Word-encoding differences among acquired dyslexics** Recent studies of acquired dyslexia have focused less on localizing the site of brain damage and more on analyzing the precise nature of the disruption in the reading processes. Behavioral experiments attempt to determine the functional organization of various language-related processes. The initial results from this new approach have suggested the category of alexia with agraphia itself contains at least two (and possibly more) distinguishable types of acquired dyslexia (Marshall & Newcombe, 1973). The two groups differ in the processes used to pronounce words: One group depends primarily on prelexical speech recoding, while the other group depends primarily on directly accessing the representation of the pronounced word using a visually based, word-level representation.

Patients in the first group pronounce words using a prelexical speech-recoding process; that is, they retrieve sounds associated with letters or a subword unit, such as letter clusters. Such patients have been referred to as **surface dyslexics** (see Patterson, Marshall, & Coltheart, 1985). The most convincing evidence of their deficit is that they tend to pronounce irregular words as though they were regular—for example, pronouncing *pint* as though it rhymed with *lint*. These readers do not appear to store and retrieve a lexically based representation of the word's pronunciation that would permit direct retrieval of irregular words.

Another group of patients has the opposite problem. They have difficulty recoding letters or letter clusters into sounds to check their pronunciation of an infrequent word or to generate the pronunciation of a nonword (Marshall & Newcombe, 1973). Such patients have been referred to as **phonemic dyslexics** (Patterson & Marcel, 1977). Phonemic dyslexics often make errors pronouncing nonwords, such as *dake* or *jub*, or infrequent

words. A common interpretation is that these patients rely primarily on lexical-level codes, which are not accessible for nonwords or infrequent words (Saffran & Marin, 1977; Shallice & Warrington, 1975). Their pronunciation errors sometimes appear to result from visual confusions. For example, they may pronounce *chair* as "charm" or *origin* as "organ." These apparently visual errors do not result from peripheral visual impairments but are specific to reading.

The word-recognition processes of phonemic dyslexics appear not to be based on word shape or any global cue. At least one acquired dyslexic was reported to have no additional difficulty recognizing words that were presented in mIxEd CaSe or words that were vertically disarranged (Saffran & Marin, 1977). Also, these patients' pronunciation difficulties vary with the linguistic properties of the word. For example, several patients were reported to have more difficulty pronouncing words with abstract referents than words with concrete referents.

Other acquired dyslexics make meaning-related errors when pronouncing words. Such a dyslexic might say "pony" when reading *horse*. These patients also make derivational errors, for example, reading "twisted" for *twist* or "buy" for *bought*. Whether these derivational errors are due to visual, morphological, or semantic confusions, however, is difficult to decide. And whether these patients are distinguishably different from phonemic dyslexics is also unclear. These acquired dyslexic syndromes are also sometimes accompanied by various aphasic problems, that is, difficulties in producing or comprehending spoken speech.

**Comparison between acquired and developmental dyslexia** Some of the acquired dyslexia syndromes are similar to developmental dyslexia. Like the phonemic dyslexics, children who are identified as developmentally dyslexic often have difficulty with the grapheme-to-phoneme translation that is required to pronounce unfamiliar words. This is one striking similarity between the acquired dyslexics and the most general characteristic of the developmental dyslexic. In addition, one might argue that there are similarities between the surface dyslexics' problems and the problems experienced by developmental dyslexics who remain slow in visually encoding words. In fact, it has been proposed that different acquired dyslexic syndromes may parallel different subtypes of developmental dyslexia (see Frith, 1985). Although the detailed investigations of these acquired dyslexics are still rather preliminary, the functional analyses of their problems do show intriguing parallels to the word-encoding problems of developmental dyslexics.

On the other hand, there is every reason to be cautious about such a parallel. There are differences among patients even within these groups. At this point, the typologies for acquired dyslexia are not entirely established or agreed upon. In addition, although studies have been done on acquired dyslexics and on developmental dyslexics, there are few direct comparisons. Moreover, a stroke does not selectively impair a single pathway without altering the rest of the system. Furthermore, these patients often learn to use compensating strategies for coping with their language deficits, and they may also be using these strategies in the experimental situations (Marcel & Patterson, 1978).

In addition to these practical difficulties, there are theoretical reasons to be skeptical about the parallel between developmental and acquired dyslexia. First, direct electrophysiological investigations of developmental dyslexics have not been consistent

in identifying brain abnormalities (Benton, 1975; Jorm, 1983). Second, the structures necessary to *acquire* a skill like reading may not be the same as those involved in its *execution*. There are intriguing disassociations among related behaviors. For example, adult patients with brain damage often show disassociation between the same skill when it is the focus of conscious attention and when it is performed automatically under aroused conditions. Luria (1970) anecdotally cited the case of a patient who could not pronounce the word *no* when asked to do so; after many frustrating attempts he responded angrily, "No, doctor, I cannot say 'no'."

Perhaps the most important reason to be cautious in drawing parallels is the neural differences between children and adults. One such difference is that a child's developing brain has more potential for one site to take over the functions of another damaged site. For example, right-handed adults who lose their left hemisphere almost always suffer severe language impairment, whereas young right-handed children who lose the left hemisphere can still acquire language and learn to read.

Only recently have researchers investigated the reading development of children who have known brain pathologies. The most significant study examined three children who had each had one of their hemispheres removed in infancy to control intractable epileptic seizures (Dennis, 1983). The child who had only a left hemisphere acquired a somewhat different constellation of reading skills than the two children who had only a right hemisphere. The child with only a left hemisphere attained a higher level of fluency and retained meaning better, not just of single words but of units larger than a sentence. At the word level, he was more familiar with the morphophonemic structure of English.

Dennis argued that the left hemisphere's advantage was not necessarily an enhanced capacity for relating sounds to signs but a better ability to master and manipulate the rules of English morphology. At the same time, the left-hemisphere child's reading was more disrupted when words were presented in isolation than in a sentence, suggesting that the left hemisphere also relied more on the syntactic and semantic context.

The two children who had only a right hemisphere also learned to read, but they relied more on visual processes to recognize words. They were not as proficient at decoding unfamiliar words and were generally deficient in inferring the morphophonemic structure of English.

Thus, research showed that the two hemispheres had different cognitive strengths. The left hemisphere plays a larger role in semantic and syntactic analysis, including English morphology. The right hemisphere is more visual or spatial; it can recognize words, but its linguistic skills are limited. Still, the children with only the right hemisphere did learn to read and understand. Thus, this study also illustrates the striking differences between children and adults. A child's brain is much more flexible and capable of reassigning the functions of damaged areas. By contrast, adults who lose their left hemisphere do not show ability to recuperate; they typically have severe and lasting language and reading problems.

The data on the neurophysiology of reading suggest caution in generalizing from acquired dyslexia in adults to developmental dyslexia. Nevertheless, the data on acquired dyslexia are informative. They support the theory of two different routes for recognizing words, the speech recoding route and the visual pathway. Moreover, this syndrome offers interesting insights into the role of particular brain structures in fluent reading.

## Summary

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Many dyslexics appear to have a relatively specific decoding problem. They do not master the context-sensitive rules of English orthography. They are generally less accurate than normal readers in recognizing words and certainly much slower. They are also notoriously poor spellers. Some people who were diagnosed as dyslexic at some point do eventually learn to read reasonably well. However, available evidence indicates that dyslexics are less likely to achieve reasonable reading skills than are poor readers.

The definition of *dyslexia* influences the resulting theory and estimates of its incidence in a population. Exclusionary approaches to dyslexia select out people who have no obvious explanation for their reading problem—for example, no abnormal schooling history or vision or auditory problems. This approach attempts to initially simplify the scientific investigation of dyslexia by selecting people for study, who are more likely to have similar problems. But the approach may result in an atypical sample of dyslexics. By contrast, the inclusionary approach selects for study any children or adults who are reading below their expected potential, irrespective of environmental, sensory, or schooling complications. The argument for this approach is that such factors may contribute to the manifestation of dyslexia. Certainly, survey data suggest that various environmental factors, as well as hereditary factors, influence the incidence of dyslexia. But exactly what kind of role these factors may play has not yet been determined. Moreover, the answers are unlikely to come from the currently available survey techniques that are used to investigate their correlation with dyslexia.

Although the dyslexic's problems are primarily manifested in reading, there are several proposals that word-encoding difficulties are symptomatic of some processing difficulty that may have nonreading consequences, as well. Of the various proposals, perhaps the most widely held is that dyslexia results from visual deficits. However, extensive evaluations of various versions of this proposal do not support visual deficits as the basis of the problem for most dyslexics. Although less thoroughly investigated, the proposal that dyslexics have difficulty in retrieving verbal information is currently a more viable proposal. Several studies have documented that dyslexics have problems when required to retrieve the names of letters, words, or visually depicted objects. Other proposals have been made concerning the possibility of a more general language or learning deficit as the basis of dyslexia. These proposals are currently being refined and evaluated, and no single proposal has unequivocal support.

Finally, we discussed acquired dyslexia and the role of various brain structures in fluent reading. Only recently have investigators begun to examine the psychological processes used when acquired dyslexics pronounce words. These studies provide some converging support for particular processes in skilled reading. Moreover, particular types of acquired dyslexia show behavioral similarities to developmental dyslexia. However, at present, it is premature to assume that the same brain structures mediate acquired dyslexia and dyslexia in children and adults who fail to learn to read normally.

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**Suggested Readings**

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Critchley and Critchley's book (1978) provides an interesting description of the reading and spelling problems of dyslexia from a clinical viewpoint. A readable short book by Jorm (1983) gives a general overview of reading and spelling disabilities. The readings edited by Benton and Pearl (1978) provide an excellent sample of the different research approaches to dyslexia. In his monograph, Vellutino (1979) presents his evidence and case against the visual basis of dyslexia. Other recent papers on the topic are in Pavlidis and Miles (1981).

The renewed interest in neuropsychology is a potentially exciting field of work. Some introductory articles on dyslexia, aphasia, and other clinical syndromes can be found in the edited volume of Heilman and Valenstein (1985). A newly edited volume describing surface dyslexia is Patterson, Marshall, and Coltheart (1985).

# **The Psychology of Reading and Language Comprehension**

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