VISUAL PROCESSES IN READING AND READING DISABILITIES

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Routledge
Taylor & Francis Group
NEW YORK AND LONDON

First Published by
Lawrence Erlbaum Associates, Inc., Publishers
365 Broadway
Hillsdale, New Jersey 07642

Transferred to Digital Printing 2009 by Routledge
270 Madison Ave, New York NY 10016
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

Library of Congress Cataloging-in-Publication Data

Visual processes in reading and reading disabilities / edited by Dale M. Willows, Richard S. Kruk, Evelyne Corcos.
p. c.m.
Includes bibliographical references and index.
ISBN 0-8058-0900-7. — ISBN 0-8058-1332-2 (pbk.)
1. Reading, Psychology of. 2. Reading disability. 3. Visual perception. I. Willows, Dale M. II. Kruk, Richard S. III. Corcos, Evelyne.
BF456.R2V57 1993
150.14—dc20 93-26065
CIP

Publisher's Note
The publisher has gone to great lengths to ensure the quality of this reprint but points out that some imperfections in the original may be apparent.

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Preface

Over the last 25 years, reading processes have been the focus of an enormous amount of research in experimental psychology as well as in other disciplines. Although the theories and models that have emerged from this research have greatly advanced our understanding, the contribution of visual processing factors to normal reading acquisition and to reading disabilities has been relatively neglected in the literature.

Reading and writing are distinct from the language processes of speaking and listening largely by virtue of the fact that a visual modality is involved. Hence, one would expect that the visual processes in reading would be the subject of a great deal of theory and research. Surprisingly, however, although there has been a considerable amount of relevant research, it is widely scattered both geographically and in terms of disciplines, and until very recently there have been no substantial reviews or books concerned with visual aspects of normal reading or of reading disabilities.

The purpose of this volume is to bring together a broad range of evidence that concerns the role of visual information in normal reading processes and in reading disabilities. Because reading processes are of concern to a diverse multidisciplinary group that includes cognitive scientists, speech and language pathologists, optometrists, neuropsychologists, psycholinguists, clinicians, and educators, this book should be of interest to a broad readership.

The volume begins with an introduction by Keith Stanovich, who places the book within the larger context of the general literature on reading processes and reading disabilities. This introduction is followed by five major sections, each including a number of chapters. Part I provides some background on the ways that visual processes have been viewed in the field of reading in the past; Part II

considers the neuropsychological foundation of visual processes in reading; Part III examines the role of basic visual processes in normal reading acquisition and in skilled reading; Part IV explores the contribution of visual processing deficits to reading disabilities; and Part V discusses some of the parameters that affect visual processing in various situations. In the concluding chapter, Keith Rayner points to future directions for research in the field of visual processes in reading and reading disabilities.

In chapter 1, Richard Venezky charts the origins and history of knowledge relating to the visual component in reading. He accomplishes this task in three ways. First, he describes the visual changes in writing which resulted from pressures to make text more readable as more people gained access to printed material. Next, he examines the contribution of early experimental psychology in providing the means to evaluate psychophysical phenomena and the early preoccupation with reaction time for reading letters and words, with eye movements, and with perceptual span and field of vision while overlooking contributions of the different types of memory. Finally, he chronicles the early investigations of reading disabilities and "word blindness" as described by Hinshelwood, Kerr, and Morgan, Orton's neurological model, and optometric explanations focusing on visual fatigue. Venezky also highlights the visual perspective contained in the educational views of Gates, Monroe, and Robinson to complete his historical account.

In chapter 2, Dale Willows and Megan Terepocki explore the phenomenon of letter-orientation reversals that, since Orton's early work in the field of reading disabilities, has been identified as a characteristic symptom of dyslexia and has been thought to provoke evidence that some type of visual processing deficit underlies reading disabilities. Their chapter begins by describing earlier historical and clinical contexts in which reversal errors became of special interest to the field of reading disabilities, and it goes on to describe the more modern context in which reversal errors may warrant a fresh look. Beginning with a discussion of some key methodological issues, they review the research evidence on *static reversals,* distinguishing them from *kinetic reversals* (transpositions). The literature is considered under the rubrics of reversals of nonalphabetic stimuli, reversals of isolated letters, letter orientation errors in the context of nonwords, letter orientation errors in the context of words, and letter reversal incidence in writing. The authors conclude that although some theorists have argued that letter-orientation reversals are of little theoretical interest in understanding reading disabilities, reversals may represent an intriguing piece in the puzzle of dyslexia, and further, more conceptually coherent research is much needed.

In chapter 3, Michael Corballis and Ivan Beale examine the work of Orton in order to clarify aspects of Orton's theory which they believe are commonly misrepresented and, at the same time, to argue for a modified version of Orton's position. They note that according to Orton the problem experienced by disabled readers is not with seeing or recognizing objects but with associating printed

words with meaning. They consider the weakness in Orton's theory to be his explanation of how the brain works. Corballis and Beale describe how present conceptualizations of brain processes argue against Orton's notion that the left hemisphere records information in its correct orientation whereas the right hemisphere records the image left-reversed, the idea that dyslexics see a reversed image. Instead, they suggest that the left–right orientation pattern of a trace is reversed not when the information is encoded, but rather when it is transferred from one hemisphere to the other and consequently when it is remembered. Corballis and Beale discuss reversal errors and the relationship between laterality and reading disability. Finally, they describe how contemporary neuropsychological theories (Geschwind, Annette, and Galaburda) are compatible with a modified version of Orton's theory that highlights the importance of directional sense and the ability to discriminate mirror-image letters in reading. Their discussion leads directly into Part II, Neuropsychological Bases of Visual Processes.

In chapter 4, Stephen Lehmkuhle explains the neurological basis of visual processes in reading. He describes visual perception as a unitary experience that gives little indication to the individual of the separate processes that make up the visual experience. He outlines the anatomical, physiological, and psychophysical organization of the magnocellular (M) and the parvocellular (P) visual pathways. He continues with a discussion of disease and M and P pathways, reporting on pathological states in which the M pathway might be selectively compromised. The chapter ends with a description of how a deficit in the M pathway may manifest itself in dyslexia, and how such a deficit may result in unstable visual processing and impeded reading.

In chapter 5, Bruno Breitmeyer outlines the literature on parallel visual processing channels. His review begins by tracing the development of the theory of sustained and transient visual channels, linking psychophysical and neurophysiological perspectives. He discusses current controversies in the area, describing how the two channels operate in both normal and disabled readers. He raises the issue that deficits in transient-like pathways across sensory modalities may have a common underlying mechanism, which could relate the diversity of symptoms that point to subtypes of reading disability.

In chapter 6, a special form of reading disability, *neglect dyslexia,* is discussed by Jane Riddoch and Glyn Humphreys. They define this unusual form of dyslexia, relate it to the wider neglect syndrome, and describe symptomology of visual neglect under different reading conditions, including text and single word reading. They evaluate several theoretical explanations, and conclude that an impairment in attentional abilities offers a suitable account of current data on visual neglect.

Part III focuses on basic visual processes in normal reading acquisition and in skilled reading. In chapter 7, Dominic Massaro and Thomas Sanocki present a theoretical framework to explain the processing of visual information in word recognition. They consider visual processes to be fundamental to reading letters,

but they emphasize that the processing of text also involves nonvisual information (orthographic, syntactic, lexical). Because letters are processed before words are identified, they present a Fuzzy Logical Model of Perception (FLMP) to explain letter recognition and this model is contrasted with an Interactive Activation Model (IAM). Massaro and Sanocki argue on the side of the FLMP as they account for a wider range of experimental findings. They conclude that letters are recognized on the basis of both global features and local or font-tuning features. This conclusion is used to explain the downfall of the i.t.a. alphabet which was restricted to modifying global features, and Massaro and Sanocki are hopeful about the outcome of studies evaluating a Graphophonic alphabet based on a FLMP.

In chapter 8, Evelyne Corcos and Dale Willows examine orthographic information from a print perspective adopting a frequency definition that highlights the probability of letters and letter sequences in various spatial positions within words. They limit their literature review to studies that do not intentionally integrate the processing of orthographic information with that of phonological and morphological information. Studies of adults and children of varying ages and reading-skill levels are presented to demonstrate a strong relationship between the acquisition of orthographic knowledge and visual familiarity. They conclude that further studies should assess the importance of exposure to print at the lexical level.

Alexander Pollatsek's chapter provides a general introduction to the topic of eye movements in reading. He highlights the finding that reading typically involves a word-by-word pattern of eye-movements, and outlines the functionality of this pattern. He reviews the literature on relevant aspects of text processing, proposes a model of eye-movement programming in reading, and, finally, compares two approaches to the use of eye-movement data for the study of text processing. He argues for the use of fixation time as an ordinal measure of cognitive processing during reading.

Continuing the theme of eye movements in reading, Alan Kennedy shows how new technological advances may have unanticipated effects on reading. Kennedy examines the effects of video display of text on eye-movement control of readers who process text presented in this manner. He begins with a review of the literature examining processing differences for text presented on screen and hard copy. He then reports data on differences in processing strategies of typists, as people who frequently encounter text on computer screens. He outlines possible mechanisms to explain the differences, introduces the notion of *optimal viewing positions,* and reports recent data on eye-movement control of typists and nontypists as a function of screen refresh rate. He shows that typists adopt a specific reading strategy when reading text, even in nontyping situations, which involves an increased frequency of small within-word saccades produced in response to pulsation-induced mislocations of eye-movements. He reports that the effects of screen pulsation are observed at refresh frequencies well above

estimates of normal fusion, and suggests that increasing the refresh rate of displays may reduce the perceptible flicker of screen-presented text.

In chapter 11, Laurie Beth Feldman examines skilled reading in Serbo-Croatian, a language that can be written with the Roman or Cyrillic alphabet. This provides a unique opportunity to study visual effects relying on the features of the alphabet of the text. Feldman reviews studies of words and pseudowords presented in the same alphabet or in the two different alphabets at pre-lexical and post-lexical stages of processing. She concludes that the alphabetic context primarily helps to augment the processing of phonologically ambiguous words, and that this effect, therefore, originates in the mapping of phonemes and graphemes.

In chapter 12, Dale Willows, Richard Kruk and Evelyne Corcos explore the role of visual processing deficits in reading disabilities. Their review scrutinizes a broad range of literature addressing the fundamental question of whether or not there are disabled/normal reader differences in basic visual processes. The literature is organized around the stage of visual processing examined, early or late. Studies that involve assessment of the processing of visual information within the first few hundred milliseconds after it reaches the eye (i.e., reflecting sensation and perception) are included in the section on early visual processing whereas studies that involve retention, recognition and/or reproduction of visual information after it has disappeared from view (i.e., reflecting memory in addition to perceptual processes) are included in the section on later visual processing. On the basis of a critical examination of this literature directly investigating disabled/normal reader differences in early and later visual processes, the authors conclude that there is a need to reexamine the widely held belief that visual processing deficits are not related to reading disabilities.

In chapter 13, Catherine Watson and Dale Willows take a different tack. By reviewing the large literature on subtypes of learning/reading disabilities, they address the question of whether there may be a visual-processing-deficit subtype among the reading disabled. Many clinicians and researchers have long argued that the reading disabled represent a heterogeneous group, and some have suggested that there may be relatively homogeneous subgroups or subtypes among the reading disabled. Both clinical and multivariate statistical approaches have been used in attempts to reveal subtypes among the reading disabled. As the authors point out, this literature involves diverse approaches to subject selection and widely varied test batteries. Nevertheless, they argue that, taken together, the subtyping literature has produced considerable evidence that disabled readers differ among themselves with respect to their visual processing abilities. Watson and Willows conclude by raising several possibilities to explain the fairly consistent finding of a visual-processing-deficit subtype among the reading disabled and by suggesting a focus for future research.

In an extended review of the current literature of early visual processes and reading disability, William Lovegrove and Mary Williams describe the converging evidence from psychophysical and physiological investigations showing that

a large proportion of disabled readers are deficient in transient visual processing. Referring to studies of visual masking, they report that the nature of the deficit involves the time course of visual processing; the transient system of disabled readers responds less efficiently than that of normal readers, resulting in a less effective pattern of inhibition of the sustained visual channel response. They also outline recent studies indicating that temporal aspects of transient system functioning can be affected by the physical properties of the text—namely wavelength. The authors end by suggesting that a normal pattern of visual processing in disabled readers can be reestablished depending on the wavelength properties of text.

In chapter 15, John Stein summarizes research examining "visual dyslexics"—children who exhibit deficits in ocular-motor control—from a variety of perspectives. He provides evidence showing that many disabled readers exhibit unstable binocular fixation. This results in visual confusion and leads to the perception of unstable visual images. Moreover, these children have poor visual location sense, which makes words appear jumbled, and this may explain the difficulties that disabled readers experience in reading nonwords. He provides data showing that monocular occlusion may lead to improved binocular stability and, ultimately, better reading performance. Finally, he relates the findings of studies of phonological and visuospatial deficiencies, suggesting that both types of deficiency may arise from a common developmental disorder, possibly involving the magnocellular neural system.

Philip Seymour and Henryka Evans also examine the connection between visual processes and dyslexia. They propose that reading difficulties in dyslexia may occur at several different stages in their model: in early visual processing, in either a visual (object) processor or a visual (orthographic) processor exclusive to processing print, or in the central reading processes that incorporate higher cognitive and language aspects. Seymour and Evans present evidence reinforcing the notion that dyslexics represent a heterogeneous population and demonstrate that some dyslexics have a prominent difficulty at the visual orthographic level. They conclude that visual deficits in dyslexia reside in a visual orthographic processor.

In chapter 17, Richard Olson and Helen Forsberg outline studies of eye-movement behavior of normal and disabled readers in reading and nonreading tasks. The evidence they report indicates that there are no differences in eye-movement behavior between disabled and reading-age-matched control groups. Minor differences between disabled and chronological-age-matched control groups are not attributed to visual processes. Their findings are contrasted with earlier research showing significant differences in eye movements between normal and disabled readers. The authors argue against the use of eye-movement measures as screening tests for reading disability, or the use of remediation practices that focus on eye-movement patterns. Research investigating individual differences in eye-movement behavior is also reviewed. The authors report sig-

nificant correlations between reading and nonreading eye-movements. They also discuss individual differences in eye-movements in relation to performance on visual and language tasks, as well as genetic influences. Evidence of genetic involvement in comparisons of identical and fraternal twins is reported. The chapter ends with the authors drawing a link between the eye-movement data reported and findings of transient channel deficits in disabled readers, and suggesting the possibility of a common underlying neurological deficiency for both visual and phonological processing deficits.

In chapter 18, P. G. Aaron and Jean-Claude Guillemard examine the relationship between developmental dyslexia and visual processes, particularly with reference to artistic skill. They maintain that the contribution of visual memory as an independent component of reading is not clearly established. The status of visual memory in reading is examined by raising the questions of whether word recognition and spelling skills can come about by superior visual memory alone, and whether visual memory skills are also related to superior orthographic memory. These questions are addressed in a novel way by presenting case studies of well-known artists who have shown evidence of developmental dyslexia. It is assumed that artists have superior visual skills, and that their symptoms of dyslexia cannot be attributed to visual skills (of the type involved in the creation of works of art). On the basis of their analysis, the authors conclude that superior visual processing skills can be observed with disabled readers. They point to other, nonvisual processing skills that may have contributed to the reading difficulties of the artists studied.

Part V, the last section of the book, focuses on optometric and ergonomic parameters influencing visual processes. In chapter 19, Ralph Garzia discusses the association between visual functioning and reading from a clinical, optometric perspective. He begins by outlining the visual functions required for efficient reading, including accurate acuity, oculomotor control, accommodation and vergence responses, and the impact of letter size, illumination, contrast, and glare. He then discusses common visual abnormalities observed during reading, as well as reading-behavior and perceptual abnormalities. He outlines the relationship between visual skills and reading, touching on studies of the relation between visual anomalies and reading disability, showing that a considerable degree of confusion and misunderstanding remains in this area. He further discusses correlations between visual functions and reading performance, as well as developmental, reading level, and subtyping issues. The chapter ends with a discussion of visual assessment and screening practices for optometric visual deficits in disabled readers.

Arnold Wilkins argues, in chapter 20, that visual discomfort associated with reading is a consequence of successive lines of text resembling a stripe pattern. Some individuals are much more sensitive to the effect of stripes and therefore are more likely to experience eye-strain, headaches and visual distortions when reading. Wilkins describes modifications to minimize these adverse effects: cov-

ering the lines not being read; wearing tinted glasses with the tint specifically selected for an individual; and altering the spatial and temporal characteristics of text to improve its perceptibility. Wilkins proposes a theory of visual discomfort to explain the phenomena and presents supporting evidence from children with visual dyslexia.

In another report of unanticipated consequences of a new technology, Richard Kruk's chapter outlines research concerned with the effects of computer monitor presentation of text on reading performance. This chapter focuses on legibility and ergonomics issues, discussing characteristics unique to computer-presented text that may affect reading performance. He outlines both hardware- and software-dependent factors found to significantly affect visual processing and reading. He ends by suggesting that a feasible model for explaining monitor legibility and effects on reading should be based on the spatial frequency characteristics of monitor-presented text.

In the concluding chapter, Keith Rayner discusses the direction of research and theory in visual processing as it relates to normal and disabled reading. He does not foresee a paradigm shift as a result of new information in the field. Instead, he expects new information, particularly about neurophysiological mechanisms associated with reading, to simply refine existing models. In the field of dyslexia, Rayner submits that both visual perceptual and language deficits probably contribute to reading disabilities. He suggests, however, a move away from a disease and/or single-cause model of dyslexia in order to acknowledge the diversity existing among dyslexics, evident in their reactions to remedial interventions. Finally, Rayner argues that an understanding of dyslexia is contingent on gaining a greater understanding of skilled reading.

—Dale M. Willows
—Richard S. Kruk
—Evelyne Corcos

Acknowledgments

Thirteen years ago, after having spent more than a decade as a basic researcher in the field of reading, I (the senior editor) took a sabbatical leave from my position in the Department of Psychology at the University of Waterloo and undertook a clinical internship at a highly respected learning center (The McGill-Montreal Children's Hospital Learning Center). There I had the privilege of working with an outstanding team of clinicians—with credentials in such fields as psychology, education, linguistics, and communication disorders—who, for many years, had been assessing students' learning disabilities and developing and implementing programs for them. By working with these experts, I hoped to determine whether the theories and models emanating from basic reading research seemed to have validity and utility in the real world of practice. As a result of my experiences there, I became convinced that what seemed relatively clear cut in theory was far from it in practice. In particular, as someone whose primary research program was focused on the role of linguistic (semantic, syntactic, and phonological) processes in reading, it came as a genuine shock to me to discover a range of phenomena in the reading and writing of the learning disabled that seemed to suggest an involvement of visual processing deficits, in addition to linguistic deficiencies. At the time, the psycholinguistic view was dominant in the field of reading, and reading disabilities were ascribed to linguistic deficits in phonological, morphological, semantic, and syntactic processes, to the exclusion of visual factors.

In an attempt to explore what role, if any, visual processes might have in reading disabilities, I (with Evelyne Corcos) undertook an extensive literature review. One puzzling finding from the review was that, although few North American researchers seemed interested in the role of visual factors in reading

disabilities, researchers farther afield, in Australia, New Zealand, the United Kingdom, and some other European countries were involved in programmatic study of the visual processing of disabled readers. In an attempt to better understand the motivation for the work that was going on overseas, I travelled on another sabbatical in 1987 to meet William Lovegrove at the University of Wollongong in Australia and Michael Corballis at the University of Auckland in New Zealand. Both of these visits encouraged me in my growing conviction that "the case"—concerning the potential relation between visual processing deficits and reading disabilities—was not yet closed, and that it had been closed prematurely in North America, probably because of the Zeitgeist in experimental psychology, as much as any weight of evidence.

Taken together, then, both clinical observations and careful review of research evidence led me to conclude that it was time for a fresh look at what role visual processes have in normal reading and at how inefficiencies in visual processing might impact on reading performance and skill. Thus, I set out to bring together the latest evidence concerning the nature of the involvement of visual processes in normal reading and in reading disabilities. This book is the product of that effort.

Because the topic of "visual processes in reading and reading disabilities" was fundamentally unpopular among most North American reading researchers, the plan for this book would never have been actualized without the help and inspiration of a number of people. For the role they had in "opening my eyes" to the complexity of learning disabilities in reading and writing, I am greatly indebted to the staff who were at The McGill-Montreal Children's Hospital Learning Center during my sabbatical there in 1980. Very special thanks are owed to Margie Golick and Sybil Schwartz who shared so generously of their knowledge and skills, and who have remained as special friends and unpaid consultants over the years since. For their encouragement and very helpful suggestions in the early planning stage of the book, I am also greatly indebted to Bill Lovegrove and Mike Corballis. I found in them an openness to ideas that were virtual heresy in North American theoretical circles at the time. Bill Lovegrove offered a wealth of suggestions that had considerable impact on the form and content of the book. Mike Corballis, Dick Venezky, Uta Frith, John Kershner, and Max Coltheart also made suggestions that were most helpful in establishing the final list of contributors. My current and former students, particularly Evelyne Corcos, Richard Kruk, Megan Terepocki, Karen Sumbler, and Catherine Watson, have served as a source of intellectual challenge and enormous support throughout this endeavor.

At a personal level, I want to express my deepest appreciation and affection to my partner Jack Quarter who has been an unfailing source of confidence and encouragement for me. Without his patience and love I would certainly never have been able to see the project through.

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Introduction

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A book such as this is long overdue. Because the reading process begins with print arrayed visually on the page, one would think that visual processes would have been one of the first topics to be studied by reading researchers and one of the most intensely investigated. However, the history of reading research is often curious (Venezky, 1977). Although the visual perception of words has at times been the subject of intense scrutiny by experimental psychologists (e.g., Carr & Pollatsek, 1985; Estes, 1977; Paap, Newsome, McDonald, & Schvaneveldt, 1982) processes of visual perception have often been neglected by reading researchers. General theories of reading often give short shrift to visual processes. The knowledge of visual word processing gained from the investigations of experimental psychologists has not been integrated into general reading theories.

At times, this work seems to have been willfully ignored by the reading education community. A case in point concerns the research on the functional visual stimulus in reading using eye movement technologies (see Balota, Pollatsek, & Rayner, 1985; Kennedy, chap. 10, this volume; Pollatsek, chap. 9, this volume). Proponents of top-down theories of reading that emphasize hypothesis testing as a processing mechanism (see Stanovich, 1986, for a discussion) have chosen to ignore findings indicating that, during reading, the sampling of visual information is relatively dense and that visual features are not minimally sampled but instead are rather exhaustively processed, even when the word is highly predictable (Ehrlich & Rayner, 1981; Pollatsek, Rayner, & Balota, 1986).

Work on visual processes in reading has had most of its impact on theory through discussions of the causes of reading disability. The idea of visual deficits as a cause of reading disability has, of course, been much discussed. However, this discussion—for all its popularity in the general media—has not been

matched by a commensurately intense research effort. This volume collects some of the best work on the possibility of visual processing deficits in dyslexia from ongoing programmatic research efforts. One thing that has hampered efforts to understand the role of visual processing in reading disability is that the small body of research that does exist is scattered throughout numerous books and journals—some of the latter being sources (e.g., *Vision Research*) that are not regularly read or cited by readers of the more mainstream reading research literature (e.g., *Reading Research Quarterly*). We have, for a long time, needed an edited volume that brings some of the best of this work under one cover.

Another factor that has hampered our understanding of the role of visual processing in reading disability is that the issue has been couched in the form of a debate. There is, of course, nothing wrong with a debate per se. But unfortunately—as often happens in the education field—this debate was set in an overly simplified, either/or fashion where a gain for one hypothesis (e.g., phonological processing deficits) was automatically seen as a loss for another (e.g., visual processing deficits). Possible complexities such as the co-occurence of processing deficits were likely to be ignored. This volume is most definitely not in the tradition of these shopworn debates.

The general approach taken by the editors of this volume is akin to that adopted by Marilyn Adams in her monumental synthesis of research on beginning reading: *Beginning to Read: Thinking and Learning About Print.* When commissioned by Congress to produce a summary of what is known about beginning reading and the teaching of reading, Adams chose not to couch her work in the language of the phonics versus whole word or phonics versus whole language debates. Instead, what Adams did was to place her entire discussion of beginning reading within the context of general models of reading-related processes in cognitive psychology. Thus, when Adams did begin to discuss more specific aspects of teaching, classroom practice, and the debate over phonics, those issues were grounded in the complexity of general models of complex information processing (including connectionist modeling).

The approach taken by the editors of the current volume is similar in that, via a judicious choice of topics and authors, they attempt to ground the debate about the role of visual deficits in reading disability in what is known more generally about visual processes in reading and the neuropsychology of visual processing. If this book had no purpose other than to foster a more complex debate about visual deficits and to set the debate in the context of information processing and neuropsychological theories of reading, it would have achieved something of scientific importance. But in addition to this, the book should help to more fully integrate knowledge about visual processing into general theories of normal reading.

In short, this volume is an ideal place for students to begin their study of visual processes in reading. Additionally, it should command the attention of even those investigators whose research has focused on language difficulties as

the cause of reading disability (myself among them). This volume should help to ensure that investigations of differing processing loci for reading disability do not take place in totally different literatures with no cross-fertilization. There are several edited volumes that collect data and theory on phonological processes in reading (e.g., Brady & Shankweiler, 1992; Shankweiler & Liberman, 1989; Stanovich, 1988). This volume is unique in providing a companion work on visual processes, but one set within a broad framework. I predict it will become a benchmark publication.

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BACKGROUND

1 History of Interest in the Visual Component of Reading

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Reading is a psychological process that is, under normal conditions, driven by visual input that initiates recognition and comprehension activities. That the reader interacts with the text, integrates previously acquired knowledge with local text information, and generates hypotheses about what might occur next in the text does not negate the critical initiation role played by the letters, words, punctuation, and other graphic characteristics of the page. Just how the optical and neurological systems transform these light–dark contrasts into meaningful information has occupied several generations of experimental psychologists, neurologists, and ophthalmologists. What we now know about visual processing in reading is amply summarized by the chapters that follow. The mission of this chapter is to explore the origins of this knowledge, that is, the history of interest in the visual component of reading.

The core of this chapter is a review of early work in experimental psychology that involved reading. This is the period of Cattell and Dodge, Quantz and Dearborn, Javal and Gates, and of the chronoscope, the Cattell fall screen, the plaster of Paris cornea cup, and the spark record. A parallel interest is the history of investigations of reading disabilities—the realm of Hinshelwood and Orton, of Gates, Monroe, and Robinson, and of many others. But a third area is also of interest to this chapter because it provides clues to the extent to which visual considerations influenced the evolution of writing systems and of the English alphabet in particular. The development of Egyptian and Sumerian writing, of the Phoenician syllabaries, of the Greek and Roman alphabets, and of the letter styles of these alphabets provide a testing ground for hypotheses about visual considerations in the evolution of writing.

Although the scribes in the Nile valley who were responsible for the transition

from hieroglyphic to demotic writing left no committee meeting records or design statements, we can nevertheless inspect the various forms of writing through this transition and make judgments about their impacts on the reader and the writer. Similarly, we can analyze the differences between Carolingian minuscules and Gothic book hand and make parallel judgments, and so on across the vast set of changes in scripts and manuscript styles that collectively constitute the history of writing and printing. The search in these cases is both for evidence that visual considerations potentially motivated a change and for evidence to the contrary. That is, changes that make manuscripts and printed pages more difficult to read are equally important because they indicate that the requirements of the reader were either not understood or were secondary to more pressing issues, such as the need to conserve parchment.

This chapter attends to three major areas where the interests just described are manifest: first, the premodern history of reading and writing; then the first 50 years or so of experimental psychology's investigations of reading and spelling; and finally the earlier studies of visual properties in reading disabilities.

THE VISUAL ELEMENT IN PREMODERN WRITING

In the 6,000 to 8,000 years that have intervened since the earliest records of writing, dramatic changes have occurred in the symbols employed to represent sound and meaning, in the marks deployed to indicate grammatical and semantic boundaries, and in the format of the manuscript and printed page. Egyptian and Sumerian logograms yielded to syllabic symbols, and in Phoenician and Greek cultures, to an alphabet. Phoenician letter forms were redrawn in a variety of forms to yield lapidary Roman capitals, uncials, half-uncials, Carolingian minuscules, gothic, italic, Bodoni, and many other styles. Space became a standard word boundary marker; periods, commas, colons, and the like were assigned respectable roles; titles and subtitles were incorporated; and pages were numbered.

From the boustrophedon writing of the oldest Greek inscriptions, with no word divisions and with the direction of reading changing from left to right and from right to left at alternate lines, to the manuscript book that coexisted with the first printed specimens of the mid-15th century, the appearance of texts was radically transformed. To what degree do these changes indicate an awareness of the visual processing needs of the reader? Can we locate within the transformations that occurred in writing systems, alphabet styles, and page characteristics, any tendencies toward more scannable and more readable documents? Can what we know now about the visual processing habits of the reader help explain any changes that occurred prior to the modern, research-based period?

This section explores this question, bringing in evidence from the period that extends from the earliest records of writing until the adoption of "modern" type styles and page formats in the 16th century. The basic conclusion presented here purports that the reader's ability to extract sound and sense rarely can be invoked to explain changes during this period. The premodern period, for reasons presented shortly, was not a time when visual processing was consciously or unconsciously considered. Exceptions do exist, for example in the introduction in the 7th century of chapter divisions in biblical texts (Saenger, 1972), but the majority of changes that might be attributed to visual considerations could also have been motivated by nonvisual factors.

The Premodern Reader

In considering text and alphabet design prior to the modern period, it is important to clarify the potential audiences involved in each period. Prior to the Renaissance, the reading public was limited to a relatively small percentage of the population in most countries. For ancient scripts, the audience was even more circumscribed, consisting primarily of scribes, and a limited number of bureaucrats and learned noblemen. Ancient Greek texts could be written without word divisions because only a small number of individuals were expected to read them, and most of these people were scribes themselves. When Judaism centered on the temple in Jerusalem, the holy texts were read mostly by the priestly group that administered the temple rituals. A Semitic script that recorded only consonants was adequate for these situations. But with the destruction of the Second Temple and the diaspora, sacred texts were read by a multitude of rabbis and teachers, dispersed throughout the known world. Vowel marking systems were required to ensure uniformity of pronunciation.

Similarly, the elaborate abbreviation systems of Greek and Latin were easily adapted for English at a time when most of the those literate in the vernacular were clerics. But with the widespread literacy that evolved through the Renaissance and post-Renaissance periods, esoteric abbreviations were a barrier to understanding and were complicated to teach; consequently they were reduced to a handful by the middle of the 16th century.

A second factor to consider is the nature of reading itself. Although some learned individuals even from classical times probably read at more than 250 words per minute silently, the vast majority of readers prior to the time of Chaucer probably read slowly and orally. Although opinions differ on the nature and extent of silent reading prior to modern times (cf. Chaytor, 1945; Hendrickson, 1929; Saenger, 1982), most who write on this topic tend to agree that silent reading was not the norm until at least the 15th century, if not later. Without the need to scan quickly and to read silently (and therefore rapidly), many imperfections in script and format could be tolerated.

Influences on Script and Format

What influenced change in script and page format prior to the modern period? Three factors appear to be especially influential: technology, cost, and impression on the reader/viewer.

Technology. A common theme that extends from the earliest recorded times until almost 100 years after the introduction of movable type printing is the priority of scribal needs over reading ease. In each case cited here, however, the technology of writing introduced the primary constraints. For example, cuneiform evolved in Lower Mesopotamia where clay was readily available and where a technology developed very early for its acquisition and use. The predecessors of cuneiform were pictographs and then so-called line characters, developed through simplification of the pictographs. In time a syllabary of about 350 symbols developed, each symbol composed of a different combination of wedge-shaped signs. Changes over time in the forms of the symbols appear to have been dictated by the constraints of the writing system, which consisted of soft clay tablets into which the symbols were recorded through the pressure of a reed stylus, rather than through concessions to the reader. In reviewing the transitions from outline characters (c. 4500 B.C.), to archaic cuneiform (c. 2500 B.C.), to Assyrian (c. 700 B.C.), to late Babylonian (c. 500 B.C.), Sarton (1952, p. 64) speculated, "As the speed of writing increased, the characters were necessarily simplified; various forms of cursive or shorthand changed the appearance of the script profoundly."

A similar argument can be made for Egyptian hieroglyphics, which were inscribed on papyrus with a reed pen. But given the greater freedom for scribal innovation that such a technology offers over that of the Sumerians, a wider range of symbol forms could be incorporated. Hieroglyphics are assumed to have descended also from an earlier pictographic system that was simplified over time to facilitate writing. In time, the hieroglyphic system was simplified even further to produce a cursive or running hand (the hieratic script) and then reduced further to a shorthand, called the demotic. Both of these latter two scripts were visually divorced from the original hieroglyphic symbols, thus once again favoring the needs of the writer over the reader.

Once alphabets were fully developed, letter styles often developed in response to technological considerations. For example, Roman stone carving led to the design of what are called lapidary Roman capitals or Trajan capitals, after the inscriptions incised on a column erected by the emperor Trajan around 114 A.D. These letter forms are highly geometric and are especially adapted for chiseling into stone. For writing on parchment or papyrus, rustic capitals, a more condensed alphabet with thinned verticals, was more common. According to Boyd (1973, p. 61), "Practical writing habits are . . . seen to be partly responsible for the changing styles of book hands through the centuries."

Cost. A second factor that took precedence over visual processing was production cost, as measured by the amount of writing material consumed and the amount of time required by the scribe. The former consideration led to techniques for crowding as much writing as possible on the page; the latter led to scripts that were easy to produce. Until modern times, writing materials were relatively expensive. Even paper production, until the introduction of wood pulp, was an expensive component of book making. Under Tiberius, papyrus became so scarce that its distribution was regulated (*Pliny,* cited in Sarton, 1952, p. 24, fn. 14). In later times the high cost of vellum led to a search for alphabets that would allow a greater number of words per sheet than existing hands. This was one of the motivations for the development of the Carolingian minuscules under Charlemagne (Boorstin, 1983, p. 496). By the 13th century, as the demand for parchment rapidly increased, new scripts were introduced with more condensed letters. One of these, Gothic, is estimated by Jackson (1981) to have required only one-third of the page area consumed by the same height Carolingian letters.

Besides developing scripts that were more condensed, medieval scribes originated an elaborate system of abbreviations for Greek and Latin that were, by the Norman Conquest, established in English documents. This system was fully developed by the year 1200, after which no new abbreviation marks were developed for Latin. A major expansion in the use of abbreviations occurred in the 13th century with the introduction of the Gothic book hand. This use of abbreviations was "an attribute which makes Gothic writing rather cryptic and much more difficult to read than the best handwriting of the twelfth century" (Boyd, 1973, p. 64). During the late Middle Ages a number of the abbreviation signs fell into disuse but the system of abbreviations was carried into printing and survived for another several centuries before being reduced to the two basic forms we have today. Speeding this decline was an English act of 1731 that required the use of English in domestic records, "replacing Latin, French, and any other language," and specified that all writing in such documents be "in words at length and not abbreviated" (cited in Hector, 1966, p. 23).

The consequences of expensive writing materials were more crowded and highly abbreviated texts, as attempts were made to pack as many words as possible into a given area. Classical Latin scribes did not ordinarily separate words; where ambiguity would result, however, either spaces or a point (*punctum*) was used. The avoidance of word spaces should not be taken as evidence for a lack of understanding of the concept of word, however, as suggested by Saenger (1982). Glossaries, interlinear word glosses, and various mechanisms for separating words in sentences are ample proof of a word sense from this and from earlier periods. (In Hebrew and Arabic, for example, special forms of letters developed for word-final position. In Arabic this was extended to other word positions and to a larger number of letters than Hebrew.)

Impression. Writing, particularly through the medieval period, often served to impress or to awe the semiliterate and the illiterate. Many early English charters served this purpose, as did many ecclesiastical documents. The *Book of Kells,* a beautifully illuminated Irish text from about 700 A.D., is a stunning example of this function of writing. Although it contains the earliest example of Irish half-uncial script, from which lowercase letters evolved, and elaborate, multicolor artwork, the text itself is riddled with errors. "Parts of sentences are omitted, a whole page is repeated by accident, letters had to be rewritten to replace incorrect ones, and there are other defects in the organization" (Jackson, 1981, p. 60). Few attempts were made by the scribes who worked on the book to correct the textual errors. "What seemed to matter most to the scribes who made this book was the magical pictorial imagery they were weaving for the eye of the mind" (p. 61).

Readership. As already mentioned, a number of orthographic and graphic devices have evolved under the pressure of an expanded readership for a script. Hebrew, for example, was for centuries written only with consonants. Speakers of the language could, with context, supply the missing vowels because Hebrew, like the other Semitic languages, distinguishes meanings primarily with consonants, using vowels to mark grammatical forms. In time, several "weak" consonants (*aleph, he, waw, yod*) began to appear occasionally as indicators of vowel quality. These *matres lectionis* or "mothers of reading," eventually became regular vowel indicators, thus producing a form of writing called *scriptio plene.* But *scriptio plene* could only indicate 4 of the 10 vowels reconstructed for ancient Hebrew and therefore did not result in a full alphabetic system (Gelb, 1963). In the 8th century of the common era, however, at least three different systems for indicating complete vocalizations evolved: Babylonian, Palestinian, and Tiberian. The latter two were primarily superlinear, the last, mostly sublinear. Of these three, only the Tiberian has survived (Chomsky, 1957). As stated earlier, the primary motivation for the vowel indicators was the expanded and dispersed readership that evolved after the destruction of the Second Temple. Because correct pronunciation of the holy scriptures was desired, and a small group of priests no longer were the main readers, a complete system for generating pronunciation became a necessity.

English spelling represents another case where expanded usage of an orthography led to concessions to the reader. Although English orthography evolved toward a standard of sorts through the Renaissance, it was not until English was restored as the language of Parliament that standardization of spelling became an issue (Fisher, 1977). Yet even after the introduction of printing, spelling regularity was often sacrificed to printing convenience. For example, many English words retained a final *e* in the 15th and 16th centuries, even though the *e* was no longer pronounced. The early English printers would sometimes include or delete the *e* to achieve proper justification of a line.

The Minim Problem

The clearest evidence for visual considerations in orthographic or graphic changes prior to the 16th century occurs in relation to what is called the *minim problem*. By the late 12th century, a condensed, upright form of Carolingian minuscules had developed, with most of the curves excluded. Downstrokes tended to be heavy, with horizonal and diagonal connectors quite thin. A succession of three downstrokes might represent *in, ni, m, iii, ui, iu, or w*.

> The risk of misreading is perhaps at its greatest when the manuscript presents a succession of "minims," the short perpendicular strokes which in varying numbers compose the manuscript letters *i* (often equivalent to *j*), *m, n,* and *u* (often equivalent to *v*). Words whose written forms consist wholly or predominantly of successive minims are particularly frequent in Latin: common examples are *nimium, minimum, annuum, immunis, innumeri.* Medieval scribes are seldom at pains to indicate the position, or even the presence, of *i,* and after 1200 very few of them make any visible distinction between *n* and *u, m* and *ni* (in, ui, iu), and so forth. (Hector, 1966, p. 27)

Beginning in the 13th century a number of changes occurred in English orthographic practices that could be interpreted as steps toward solving the minim problem, that is, steps toward making manuscripts more legible. These changes were (a) substituting *o* for short *u* in contiguity with *m, n, u,* and so forth; (b) reversing *hw* to *wh;* and (c) substituting *y* for *i* in contiguity with *m, n, u,* and so forth. Some of these changes, such as the use of *y* as a variant of *i,* resulted from similar Norman practices; others, like the reversal of *hw* occurred only in English. In the latter change, a phonologically accurate spelling (*hw*) was sacrificed for a more legible one (*wh*).

On the replacement of *u* by *o* when *u* represented a short vowel (e.g., *wolf, woman, worm; above, dove, love; monk, money; come, some*), Scragg (1974, p. 44) agreed that visual factors were important when *u* was adjacent to *v* (which was then identical to *u*) and *w* (which was written *uu*), but doubts that this same argument can be applied to words in which *u* was adjacent to *m* or *n*. Several purely graphic changes also occurred at this time, apparently motivated by the minim problem. One was the addition of a mark over *i,* which according to Pyles (1964), developed from a faint sloping line that Middle English scribes introduced to distinguish *i* from adjacent *m, n,* and *u,* and to distinguish *ii* from *u*.

A second change was the development of a tailed form of *i,* which eventually became modern *j*. "The same cause that led to the dotting of *i* contributed largely to the formation of *j,* originally merely a lengthened or tailed *i* used finally as a more distinctive form, especially when two *i*'s came together, as in *ingenij,* or in the numerals *ij, iij, viij,* etc" (Oxford English Dictionary, Vol. 5, p. 517). *I* and *j,* like *u* and *v,* were not differentiated in early modern English writing. However, by the 16th century some writers used *i* exclusively for vowels and *j* only for

consonants. But complete separation did not occur until nearly the middle of the 19th century.

A third graphic change involved the distribution of the curved and angular forms of *u* (*u* and *v*), which were used in Old and Middle English indiscriminantly for both consonant and vowel values. Middle English scribes began to use *v* initially and *u* elsewhere, regardless of whether they represented consonant or vowel. However, when a *u* would be adjacent to *m* or *n*, an exception was made for legibility through the substitution of *v* (Pyles, 1964).

Summary

Until the masses could read and print became competitive in the marketplace, changes in writing styles, fonts, and page formats favored the interests of the writer/printer over those of the reader. Transitions from pictograms to syllabaries may have been driven as much by economy of memory as by scribal convenience, but the adoption of more condensed scripts and of elaborate systems of abbreviations were most probably driven by a desire to economize on parchment and scribal time. A few exceptions to this pattern occurred, as in the development of Carolingian minuscules under Charlemagne and in some spelling and graphic alterations to reduce confusability of script, but until at least the end of the 18th century the eyes of the reader were not a systematic consideration in writing or printing.

VISUAL PROCESSING IN EARLY STUDIES OF READING

The earliest empirical studies on the visual aspects of reading were concerned with legibility of print. In Paris in the 1790s, two typefaces were compared for legibility by measuring the closest distances at which experts could no longer read them (Updike, 1928). In 1827, Charles Babbage (of mechanical calculator fame) evaluated the effects of different shades of paper on legibility through majority vote (Pyke, 1926). But the true beginnings of the psychological investigation of reading are marked not by these early explorations of legibility but by the inauguration of Wundt's laboratory at the University of Leipzig in the late 1870s.

One of Wundt's experimental interests was the speed of mental events and the dominant paradigm for studying this factor was the reaction time experiment, with Donder's subtractive procedure used to isolate the time factors for different stages of processing (Cattell, 1888). Reading was a convenient and familiar process for measuring reaction times of mental activity, so for a brief period printed letters, words, and sentences occupied stage center in the psychological laboratory.

For our purposes the central figure in Leipzig was not Wilhelm Wundt, but James McKeen Cattell, an American who spent 3 years with Wundt as a graduate student, receiving his doctorate from Leipzig in 1886. Cattell was one of a steady stream of U.S. graduate students, including Joseph Mayer Rice, Lincoln Steffens, and Gertrude Stein, who made pilgrimages to the psychological laboratories of Germany. While at Leipzig, Cattell concentrated on individual differences, yet he is most remembered among reading researchers for his work on letter and word recognition, legibility, and the span of attention.

In two articles published in the mid-1880s (Cattell, 1885, 1886), Cattell described three seminal experiments in the visual processing of print. The first (1885) demonstrated that at brief exposure intervals, accomplished readers could read three or four randomly selected letters or two randomly selected words. This result, which contrasted with Valentius' claim (cited in Schmidt, 1917) that letters were perceived separately in word perception, was for many years cited as evidence in support of teaching reading via whole word methods.

Another experiment demonstrated that naming times for single words decreased as more words to be named were in view simultaneously. The parallel processing implied by this result is responsible for the eye-voice span first reported by Quantz (1897–1898), but not investigated thoroughly until Buswell (1920). The third study was similar to the first two, except the task was to read aloud connected and unconnected words and letters. In general, Cattell found that competent readers required about twice as much time to read the unconnected as the connected material. (On Cattell's studies, see also Dearborn, 1914.)

At the same time that Wundt was initially stocking his laboratory in Leipzig, Emile Javal, a French ophthalmologist, was studying eye movements in reading, as well as the legibility of print. Javal's discovery that the eyes in reading moved *par saccades* or jumps contradicted the prevailing views on eye control and motivated similar studies throughout Europe and later, North America (Javal, 1879).

From the middle 1880s until the beginnings of the educational testing movement (c. 1911), perceptual studies of reading were common in experimental psychology. Although the first studies were done in Europe (Paris, Leipzig, Halle, etc.), by the early 1900s active experimental psychology laboratories existed in North America, including Yale (Judd, McAllister, Stelle), Brown (Delabarre), Columbia (Cattell), Wesleyan (Dodge), Clark (Huey), and Wisconsin (Quantz, Dearborn). By 1908 three major experimental studies of reading had been published (Dearborn, 1906; Huey, 1908; Quantz, 1897–1898), a stage-by-stage processing model proposed, subvocal speech analyzed, and pronunciations of pseudowords collected. The primary issues explored during this golden era—word recognition, eye movements, field of vision, and perceptual span—are summarized here. A fuller account is given in Venezky (1984), which is the basis for this discussion.

Word Recognition

Word perception was, as it is today, one of the central mysteries of the reading process. Erdmann and Dodge (1898) demonstrated that words could be read at a distance at which their constituent letters could not be identified. This result, which was later misinterpreted as support for a wholeword instructional strategy, was consistent with Cattell's (1886) finding that the perceptual span for letters in meaningful words was considerably greater than the span for letters in random strings. Adding further support to the holistic explanation was a study reported by Pillsbury (1897) in which subjects were asked to identify words in which a letter was either omitted, blurred with an overtyped *x*, or replaced by another letter. These words were exposed for brief durations and the subjects were asked not only to identify each word but to comment on any letters that were not clearly seen. Subjects tended not to report many of the letters that were altered and in some cases even insisted that a replaced letter was clearly seen. (Omissions were detected in 40% of the cases, replacements in 22%, and blurs in only 14%.)

Opposition to the whole-word recognition school focused mainly on letters and letter features. Goldscheider and Muller (1893) found that misreadings of briefly exposed words were more frequent if certain "determining letters" were absent than if other "indifferent letters" were missing. Zeitler (1900), whose work is summarized at length in Huey (1908), derived a theory of "dominant letters" from studying which letters were reported most accurately in misreadings of tachistoscopically presented words. Messmer (1904) also found evidence for perception mediated by "dominating" letters or complexes. Long letters that projected above the line tended to dominate more than those that projected below the line, but attention during recognition pauses can also wander, allowing other parts of the word to affect the response.

In general, the German psychologists supported word recognition mediated by letters and letter groups, whereas North American psychologists argued for total form. An exception on this side of the Atlantic was Hamilton (1907), who supported neither a pure word shape nor a dominant letter theory. Hamilton, who taught at the New York Training School for Teachers, had worked as a student with many of the leading U.S. psychologists at the beginning of the 20th century: W. L. Bryan and J. A. Bergstrom at Indiana University, J. R. Angell and J. B. Watson at the University of Chicago, and E. L. Thorndike and R. S. Woodworth at Columbia, where Hamilton received his doctorate. As part of his dissertation study, Hamilton examined the reading under brief exposure times of short sentences, phrases, and words. The subjects related orally after each trial what they read, including their degree of certainty for each word or word part, and their subjective description of their impressions.

As would be expected, the subjects read more in connected sentences than they did in miscellaneous phrases, and more in miscellaneous phrases than for miscellaneous words (for the same exposure times). In a second experiment,

paragraphs were exposed line by line, with repeated exposures until full recognition was achieved. Subjects reported not only the words that they recognized but also partial impressions. Hamilton (1907) concluded that for adults, word recognition for familiar words occurred through general features—word shape, length, certain determining letters. "But when some unfavorable condition arises or when the words are strange or difficult, additional distinctions within the word are required, in which case the parts of the word must be brought more or less clearly to consciousness according to the degree of the complexity or unfamiliarity" (p. 52). Hamilton (1907, p. 53) spoke of a "conscious resort to such analysis," implying that the reader controlled the recognition strategy, deploying different procedures for different processing tasks. Included in this same report was a reference to stages of word processing, with a comment that introspection, which was a common experimental procedure at that time, was not too useful for demonstrating the various stages.

As was common at the time, Hamilton inferred that his results with adults were sufficient evidence for deciding how children should be taught. "In the first place it has been found that in every form of experiment in reading which has been undertaken, the influence of context as a condition of word recognition is strongly in evidence. . . . The value of these facts as a warrant for the pedagogical practise of presenting reading lessons in the form of whole compositions is obvious" (p. 52).

Dearborn (1906) attempted to resolve the word recognition controversy through eye movement recordings, but mistakenly assumed that changes in attention, as would occur during word perception mediated by letters, would necessarily be accompanied by fixation changes. Not finding any, he declared firmly for word shape. Huey (1908), although concluding that word form was the primary cue for recognition, hedged somewhat on the role that letters might play in this process. The general condition of word perception theories in the early 20th century, however, was aptly described by Huey (1908), who wrote, perhaps for the entire century: "It is very difficult to draw final conclusions concerning visual perception in reading" (p. 102).

Eye Movements

One of the most controversial issues in the golden era of reading research concerned the nature of perception during reading, and especially the question of whether or not perception occurred while the eyes were moving. Cattell suggested that it did, but experiments by Erdmann and Dodge (1898) and Dodge (1900, 1907) produced evidence to the contrary. For those who held that visual perception did not occur during eye movements, a further controversy developed over the inhibitory mechanism. Dodge (1900) held that optical blurring was the cause, and Holt (1903) attributed it to a central inhibitory process. (More recently, demonstrations of the correctness of Dodge's position have been pub-

lished by Volkmann, 1962, and Uttal and Smith, 1968.) Related to this issue was a conflict over the regularity of eye movements. Javal claimed that the eyes paused on every tenth letter in reading. Huey (1908), although not supporting the specific span of 10 letters, nevertheless held that eye movements were rhythmic. Erdmann and Dodge (1898), on the other hand, stressed the irregularities in eye movements due to individual differences and to differences in reading materials. In contrast to this view, Dearborn (1906) concluded that length of line, and not sentence form or subject matter, conditioned the fixation pattern. He, nevertheless, did find large individual differences in motor habits, and noted especially the differences evidenced by the same subject in successive readings of the same passage.

Much less controversial were conclusions drawn about the nature of fixations during reading. Huey (1898) observed that fixations often involved small movements of the eye around a limited area. Both McAllister (1905) and Dearborn (1906) investigated this phenomenon, the latter finding that readjustments tended to occur primarily during the fixations at the beginning and end of a line. Data were also accumulated on the number of fixations made on lines of different lengths, on the negative relationship between this variable and reading speed, and on the places within a line where the eyes are most likely to fixate. Investigation of this latter variable is perhaps the most important contribution of Dearborn's (1906) dissertation study. By comparing eye movements during successive rereadings of the same passages, Dearborn concluded that sequences of small function words required relatively more fixations than longer content words because they could not readily be fused into larger units. "Since they [prepositions, conjunctions, etc.] occur now with one word and now with another, they cannot without danger of error be fused into larger wholes, and, for that reason, they must, except where the content gives the connection, be separately perceived" (p. 85).

Dearborn (1906) was also the first to investigate the role of orthographic structure and pronounceability in reading. Using rows of unrelated nonsense words (five words per row) as stimuli, Dearborn obtained eye movement records from adult readers. From an analysis of these records and of the structure of the nonsense words, he concluded the following:

> The length of the [fixation] pause is due in part to the sequence of letters. If that is the normal or more common sequence of words, such as "werq," "wopi," "gero," "apli," "enfa," the association process is less interfered with; such combinations as "ciuo," "weao," "dpin" disappoint the association expectancy and the time taken for perception is longer. A second and perhaps more important element is that of the ease of pronunciation . . . articulation or some form of motor expression is undoubtably one of the factors which determine the length of the fixation pauses in general. (p. 65)

Although Dearborn's concept of common (i.e., English-like) letter sequences is slightly askew (the final *q* in *werq,* for example, does not occur in English

spelling), his suggestions about the role of orthographic structure and pronounceability were unusual for his time. Not until the work of E. J. Gibson and her colleagues in the early 1960s (e.g., Gibson, Pick, Osser, & Hammond, 1962) was this issue revived, and it remains unresolved today.

Eye movements returned to a position of prominence beginning in the 1920s as part of the debate over the relative values of oral and silent reading. Judd and Buswell (1922), for example, used eye movement comparisons to emphasize the differences between oral and silent reading. In the 1930s a variety of studies (e.g., Anderson & Swanson, 1937; Fairbanks, 1937; Swanson, 1937), using methodologies similar to those of Judd and Buswell (1922), concluded the opposite, that is, that the two processes were highly similar. Most of these studies made simple, correlational comparisons between oral and silent reading factors. For example, Anderson and Swanson (1937), using college students, found high correlations between oral and silent reading for pause duration, fixation frequency, and reading rate.

The first comparison of eye movements across languages and writing systems was made by Gray (1956). Eye movements and reading rates were recorded in the reading laboratory at the University of Chicago for 78 adults, almost all of whom were graduate students in universities in and around Chicago. Included were competent speakers of Arabic, Burmese, Chinese, English, French, Hebrew, Hindi, Japanese, Korean, Navaho, Spanish, Thai, Urdu, and Yoruba. No significant differences in eye movement patterns were found across the languages involved. In all cases, fixation durations for oral reading were longer than those for silent reading. The average number of words recognized per fixation also did not vary between oral and silent reading, except for English and French, where small differences were found. How "word" was defined for languages like Arabic, Hebrew, and Chinese was not described, however. (The definition, if consistent within a language, would affect only the comparisons across languages.)

Field of Vision and Perceptual Span

Cattell's studies established that the field of distinct vision and the perceptual span were different entities, the latter depending on the subject's ability to group stimuli into larger units. Erdmann and Dodge (1898) found similar results, using isolated letters, words, and sentences. Quantz (1897–98) approached this problem by interrupting the reading stimulus during reading and counting the number of words that could be produced beyond this point. The resulting eye–voice span was found to vary not only by individual, but also by place in the line where the interruption occurred. The span was longest at the beginning of the line and shortest at the end. Hamilton (1907), like Cattell (1886) and Erdmann and Dodge (1898), used a tachistoscopic exposure of sentences, but asked his subjects to

report everything they could resolve of the stimulus, including image shape and first letters. He found that even when whole words were not resolved, various word features were nevertheless correctly retained.

More typical, however, of work on span of attention during this period is a study by Griffing (1896) in which subjects from grade one through college attempted to identify briefly exposed capital letters. Each exposure contained six randomly drawn letters, arranged in two rows of three letters each. Exposure durations were 0.1s and 1s; each subject received 10 trials at each exposure duration. Subjects showed continual improvement with increasing grade level, with the advantage of increased exposure time decreasing steadily over the same age span. Although Griffing's main concern was attention, he was not willing to attribute the entire experimental effect to this factor. He was clearly aware of immediate memory problems, mentioning the "ability to receive and retain a number of simultaneous retinal impressions."

Huey (1908) also clearly distinguished between the field of vision, as measured with nonredundant materials and perceptual span, which depended on predictive ability. Earlier studies had shown that more material was generally recognized to the right than to the left of the fixation point in reading and that unusually long strings of words might be recognized in a single fixation if the words were meaningfully connected. However, with randomly selected letters, only four or five could be recognized at once. Huey (1908) also summarized work showing that with longer strings of unrelated letters (e.g., 6–7), the first and last letters were most easily recognized.

Using the letters *n* and *u,* Ruediger found that the size of the visual field varied with the size and legibility of the test letter and its distance from the eye. By measuring the reading rates and numbers of fixations per line for his subjects, Ruediger also found that the size of the visual field did not relate to either reading speed or fixation pattern. He concluded that reading rate was primarily a function of the speed of comprehension processes that occurred after word perception.

Other issues, such as the integration of information across fixations were also investigated (Dearborn, 1906; Dockeray, 1910), but by the time adequate instrumentation was available for such work, educational psychology had separated from experimental psychology and shifted its attention to schooling and testing, whereas experimental psychology was beginning its transition away from an interest in mental events, moving toward the long winter of behaviorism.

Summary

By the end of 1911 the first volume of the *Journal of Educational Psychology* had been issued and Thorndike's handwriting scale was published. Behaviorism was ready to emerge on the psychological scene, to share the foreground with educational testing and school efficiency. Research on visual factors would continue, particularly on eye movements (Fairbanks, 1937; C. T. Gray, 1917; Judd

& Buswell, 1922; Tinker, 1946), but the pace would be slower and more to the periphery of reading research. The intensity of work on visual factors and the excitement of discovery that characterized the golden era would not reappear until after the passage of the Cooperative Research Act of 1954.

DISABILITIES, ABNORMALITIES, AND ANOMALIES

Interest in the visual aspects of reading disability, abnormality, or anomaly began in the 19th century and continues to the present time. Depending on the investigator, observations on such reading defects served to further theories about brain organization, ocular-muscular functioning, or reading instruction. Three basic schools have developed on reading disability, each focusing on a different set of causes for reading malfunction and failure. They are to some degree in competition with each other, but each also has its own exclusive territory within which the other schools have no basis for trespassing. For convenience of discussion, these schools are called *neurological, ocular-motor,* and *psychoeducational,* although the names should be taken as approximate characterizations only, and not as definitions.

Neurological Functioning

Hinshelwood. The neurological school originated from an interest in acquired and congenital word-blindness and has been dominated by two camps, each centered on a different view of cortical malfunctions in relation to reading. In 1895, a Glasgow eye surgeon, James Hinshelwood, published an account of acquired word-blindness, that is, of sudden loss of reading ability after damage to the brain (Hinshelwood, 1895). In the following year, two accounts of congenital word-blindness appeared in England. One, from James Kerr, medical officer of health in the city of Bradford, mentioned briefly in an essay on school hygiene a boy of normal or above-normal intelligence who could "spell the separate letters" but was word-blind (cited in Critchley, 1964, p. 7). The second account came from Dr. W. Pringle Morgan, a general practitioner in the English town of Seaford, and was published in the *British Medical Journal* (Morgan, 1896). Morgan described some of the characteristics of a 14-year-old boy, also of normal or above-normal intelligence, who had good ability in arithmetic and algebra but could not learn to read. Morgan assumed a neurological disorder as the cause of the boy's reading failure. In forwarding a copy of his article to Hinshelwood, Morgan wrote in a covering letter that word-blindness might possibly be congenital.

Although Hinshelwood, Kerr, and Morgan are generally credited with the first published accounts of word-blindness, earlier accounts from the 19th century

have been found by Critchley (1964). For example, a professor from Montpelier named Lordat recounted his own recovery from a speech disorder, which included the loss for a period of time of the ability to read. Kussmaul in 1877 supposedly was the first to propose the term *word-blindness* for aphasic loss of reading ability where other intellectual abilities remained intact. In the early 1870s, Broadbent reported on a word-blindness case in which an autopsy revealed lesions in the left angular and supramarginal gyri regions—the first record of a connection between acquired word-blindness and cortical damage.

The term *dyslexia,* which is generally applied to cases of word-blindness where other intellectual functions are intact, has an uncertain history. According to Critchley (1964, p. 2), it was first proposed by Professor Berlin of Stuttgart in 1887 in a monograph entitled "Eine besondere Art der Wortblindheit (Dyslexia)." However, the *Oxford English Dictionary Supplement* (Vol. 1, 1972) cites an 1883 usage by Berlin (German dyslexie). *Dyslexia,* according to the first edition of the *Oxford English Dictionary* (vol. 3, p. 738) is "a difficulty in reading due to affection of the brain." This definition, published in 1897, differs from the definition of *word-blindness* that occurs in volume 12, but was not published until 1927: "inability to understand written or printed words when seen, owing to disease of the visual *word-centre*" (p. 283). Hinshelwood (1917) proposed a three-way distinction between *congenital dyslexia* (mildly backward readers), *congenital alexia* (inability to read by the mentally retarded), and *congenital word-blindness* (cases of pure reading defect where other functions are intact). These distinctions have not been widely subscribed, however.

Modern dictionaries do not fully agree on definitions for dyslexia, varying from simple statements of *reading disability* to more elaborate causal mechanisms, including *inability to integrate auditory and visual information.* The *International Reading Association Dictionary of Reading and Related Terms* (Harris & Hodges, 1981, p. 95) has what is probably the most accepted definition among reading educators: "A rare but definable and diagnosable form of primary reading retardation with some form of central nervous system dysfunction."

Hinshelwood, in spite of his failure to establish preferred nomenclature for the field, nevertheless was the most influential voice for almost a quarter of a century in the neurophysiology of word-blindness. Through case reports and two monographs (Hinshelwood, 1900, 1917), he elaborated a theory based on separate cortical areas for visual memory of letters, words, and general perceptual input. Word-blindness resulted from damage to the visual memory center for words and might not be accompanied by damage to any of the other visual memory centers. For example, in an 1898 report he described a 53-year-old man who lost his ability to read after a stroke, but continued to recognize letters and numbers normally, and could write to dictation and copy words.

His most intriguing case concerned a 34-year-old man who before he suffered a stroke could read fluently English, French, Latin, and Greek (Hinshelwood, 1902). The stroke left him aphasic, but still capable of naming letters and some

shorter English words. Some longer words could be recognized if he spelled them aloud letter by letter, but sentences in English were beyond his immediate poststroke ability. Nevertheless, he could still read Greek fluently and with some difficulty handle Latin and French. (The Greek was tested on Homer, Xenophon, and the *New Testament.*) The man became aphasic in early July 1901 and by end of September of that year had made nearly a full recovery of his reading abilities. Hinshelwood (1902, p. 361) concluded that "in the case of a person who is able to read several languages the letter- and word-visual images of each language will be grouped together forming thus a series of separate groups within the centre."

Although the term *word-blindness* has been adopted for the anomaly discussed here, it is important to note that the problem reported is not in the primary perceptual stages of processing, but in the association of an image with a name or meaning in long-term memory. Some writers have pointed out that dyslexia could result from impairment of a specific memory center or from defects in the connecting fibers between specific centers or processing areas (e.g., Lord, Carmichael, & Dearborn, 1925; Wallin, 1920). As logical as the explanations are of impairment to specific cortical areas or to interconnections, almost all of them originated without conclusive postmortem examinations. Robinson (1946), whose review of the pre-World War II neurological evidence for reading failure is among the best available, claims that Hinshelwood did only a single postmortem examination among all of the word-blindness patients he examined. Orton (1928) concluded that no postmortem had ever been done on a patient with congenital word-blindness.

Although some educational psychologists have been highly critical of neurological theories of reading failure (e.g., Gates, 1927), the evidence for a neurological connection to acquired word-blindness is difficult to refute. In almost all cases reported, word-blindness occurred after a stroke or other form of brain trauma and disappeared generally within 6 months. Hinshelwood, although not a reading specialist, adopted early in his work a sequence of tests for picture, letter, and word naming. The patient was first shown an illustrated picture book and asked to identify and name one of the pictures (e.g., "cat"). Then the patient was asked to spell the name out loud and to name letters of the alphabet from their printed forms (both upper- and lowercase). Finally, the patient was asked to locate exemplars of the selected word in a printed text without moving his lips or hands and without spelling the word aloud.

Other reports of both acquired and congenital dyslexia from early in this century showed a similar sensitivity to different components of reading behavior. Rutherfurd (1909), for example, reported a case of a 10-year-old girl who could read short, simple words (e.g., *an, of, the, if*), but not longer or less familiar monosyllables (e.g., *first, think*). She also could not pronounce words from hearing their spellings nor could she remember words pointed out to her in the text. She could, however, identify pictures easily. Rutherfurd (1909) traced the

family of his patient and found that her parents and grandparents were illiterate. Thomas (1905) also reported a family association with congenital word-blindness, as did Hinshelwood (1907), who examined four brothers with the disability. What cannot be determined from these cases, however, is whether dyslexia resulted from similar cortical defects within each family, transmitted through heredity, or if it resulted from shared combinations of environmental and educational factors, such as poor nutrition, ingestion of excessive amounts of lead or mercury, or limited schooling.

Orton. Samuel T. Orton, director of a county medical clinic in Iowa, became interested in word-blindness in the early 1920s, but unlike Hinshelwood, focused his medical attention on lateral dominance. In a series of influential publications, Orton (1925, 1928, 1937) advanced an explanation for reading failure based on developmental changes in cortical localization. According to Orton's analysis, in the early stages of learning to read, both hemispheres participate in the recognition of letters and words. That is, the images of letters and words are projected onto both the left and right associative cortices, one being a mirror image of the other. In normal reading development, the confusing images of the nondominant hemisphere, which are reversed from those in the dominant hemisphere, are repressed. Reading disability, therefore, results from a failure of the dominant hemisphere to suppress the interfering images from the nondominant hemisphere. This defect he called *strephosymbolia,* for "twisted signs," a term that has failed to gain a place in the reading disability literature outside of the Orton school.

Orton's claims of "ambiguous occipital dominance" derived in part from high correlations he claimed to have found between reading disability and left-handedness or ambidexterity, and from a high incidence of reversals in both the reading and the writing of the reading disabled. In particular, he found mirror writing to be a direct substantiation of the reversed images he hypothesized to be stored in the nondominant hemisphere. Most reading educators, in contrast, have not found merit in Orton's claims. Gates (1936, p. 352) was one of the first to reject Orton, claiming "the idea that confused brain dominance or lack of dominance should be the cause of such reading difficulties was considered too speculative to be serviceable." The idea of mirror images or engrams he dismissed as "unacceptable to most psychologists" (p. 351). More reasoned criticisms were made by Critchley (1964), who questioned why verbal symbols would show a dysfunctionality not shared by other visual stimuli—objects, scenes, pictures, and so forth. He also questioned how such an explanation could account for confusions in the lateral direction only.

Attempts to relate eye and hand dominance with reading disability have yielded mixed results and questions remain on the proper evaluation of dominance and of the relationship of eye dominance evaluated in static situations with eye dominance during the dynamics of reading. Dearborn (1932–33) and Eames

(1934), among others, report data in support of Orton's hypothesis, derived from comparing eye-hand dominance in reading-disabled groups with the same factors in controls. Witty and Kopel (1936) and Traxler (1937), in contrast, are representative of studies in the United States that failed to support Orton. Hermann (1959), who worked in Copenhagen, also arrived at a negative conclusion on eye-hand dominance and dyslexia. More recent work, particularly that of Benton (1975), has tended to reject Orton's dominance claims. Nevertheless, the Orton Society maintains a respectable following and some educators still find favor in the dominance hypothesis (e.g., Downing & Leong, 1982). Crider's summary of this work from 1934 appears to be valid today: "The opinions advanced by Orton and Dearborn are commendable as hypotheses but they are not theories and even less are they facts" (cited in Robinson, 1946, p. 42).

Ocular-muscular Functioning. With Javal's observations in the 1870s of the saccadic nature of the reading process came a parallel observation of visual fatigue from reading (cited in Huey, 1908, p. 387). With sustained reading, the eyes are not only traveling at a variety of different rates (e.g., about 8 feet per minute average for saccadic jumps and fixations combined and about 140 feet per minute average during return sweeps), but also starting and stopping about 146 times per minute. (Luckiesh and Moss, 1942, estimated that during 8 hours of reading, the ocular muscular mechanism will start and stop about 70,000 times.) Visual fatigue might involve fatigue of the retina as well as ocular muscular fatigue and fatigue of the optical pathways that transmit visual information to the brain. Although this is not a topic that is developed fully here, it was during the first half of this century an issue in the study of reading.

Besides Javal (1879), Griffing and Franz (1896) wrote on visual fatigue before the 20th century, as did a number of German psychologists. Huey (1908), in his *Psychology and Pedagogy of Reading,* devoted two chapters to the topic, one on the nature of visual fatigue and one on the characteristics of printed texts that contribute to decreased fatigue. Major texts on the topic did not appear, however, until the 1940s (e.g., Lukiesh and Moss, 1942, and Carmichael and Dearborn, 1947). The latter has the most extensive bibliography to be found on the topic up to that date, incorporating over 400 items, including a considerable number from the 19th century. The term *reading hygiene,* which included visual fatigue as one of its components, was not used much past the first quarter of this century. What was incorporated under this title became, in time, studies of visibility and legibility.

Educational Views

Other neurological explanations of reading failure exist, such as a functional maturational lag (Chall & Mirsky, 1978; Wixson & Lipson, 1991), but for the most part educators have been unwilling to accept single cause explanations for

the range of reading disabilities that are observed in the schools. For many years the work of Hinshelwood and of Orton was ignored by educators and educational psychologists. For example, neither Huey (1908), nor Wheat (1923), nor Anderson and Dearborn (1952) devoted a single line to dyslexia or word-blindness in their texts on the psychology of reading. Brooks (1926) provided a neutral, brief description, listing it as one of 13 causes of slow silent reading, along with defective vision, lack of interest, and so forth. Gates (1927) was outright hostile toward neurological explanations, whereas Monroe (1932) and Robinson (1946) viewed faulty neurological development as one of a number of potential explanations for reading failure. Their specific views are the subject of the next section.

Gates. The educational testing movement that began in the second decade of this century with the publication of Thorndike's (1910) handwriting scale led rapidly to a national industry in reading diagnosis and assessment. So overwhelming was the educational fascination with reading tests that by the 1920s reading research articles on testing dominated over all other topics. But the times were ripe for assessment and accountability. The massive immigration movement that extended from the 1880s until the beginning of World War I when the doors were shut had brought a dramatic increase in school enrollments. Methods were needed to determine objectively where students should be placed when they entered the school system. Then, silent reading, which began to replace oral reading at the end of the 19th century as the dominant mode of school-based reading, created a further need for objective assessment. With oral reading, the teacher need only listen, but with silent reading some probe was needed to determine if mind and eye were synchronized and efficient. Which was cause and which was effect may not be clear in this environment; silent reading may have been an outcome of overcrowded schools where teachers could not cope with either individual student needs or the din from unsynchronized oral reading. Objective, group-administered tests provided a level of assessment that was no longer possible with individual oral presentation. But whichever came first, tests were adopted wholeheartedly and have remained in the schools ever since.

In parallel with objective, standardized tests came a concern for reading failure, for the students who in the past were simply considered slow or backward. Just as Binet and Henri developed intelligence tests to identify students who had potential for learning but were not progressing as expected in the French schools, diagnostic tests for reading were developed to determine what, if anything, might be done with disabled readers. Among the work done in the first four decades of this century on diagnosis of reading disabilities, the most influential was that of Gates and his colleagues at Teachers College, Columbia University. Gates, who had been a student of Thorndike at Columbia, published *The Improvement of Reading: A Program of Diagnostic and Remedial Methods* in 1927 and a revised edition in 1936. The first edition was based on studies done

prior to the end of 1926 and showed the eclectic clinical model of reading diagnosis that remains in place today.

Gates' view on reading difficulty was that "most difficulties, ranging from the least to the most serious, are . . . due primarily to failures to acquire techniques that might have been acquired had the right guidance been given at the right time" (1936, p. 17). On the Hinshelwood/Orton notions about neurological causes for reading difficulties, Gates answered,

> It is recognized that various weaknesses and defects of the bodily organs and mechanisms involved in reading may prove to be handicaps, often very serious ones. Similarly, certain individual physical or mental characteristics, such as left-handedness or volatile personality, may predispose a pupil to develop difficulty. Thus, despite the fact that physical, mental and emotional obstacles are numerous and serious, it is believed that most children of Intelligence Quotients above 70 may be taught to read if optimal methods are employed. (p. 18)

The test battery that Gates assembled covered almost every aspect of reading considered important today: vocabulary and comprehension, phonics and auditory perception, eye movements, educational background and motivation, and so forth. For visual processing, Gates placed especially strong emphasis on left-to-right visual scanning and on properly sequenced instruction. He was probably the first to recognize that word recognition habits often resulted almost directly from the classroom methods used to teach word recognition. In an earlier study (Gates & Boeker, 1923), he had found that when beginning readers were introduced to new words with differing lengths, the children selected word length as a distinguishing feature, and when trained on words of the same length, they selected small details of each word idiosyncratically. (This subject was not revived in reading research until the work of Marchbanks & Levin, 1965, and Williams, Blumberg, & Williams, 1970.)

Drawing on work by Hildreth (1934), Gates also argued that letter and word reversals were totally normal and expected for beginning readers. Shape, but not direction, was a salient cue for object recognition in the child's world up to the time that letters and numbers are encountered. Remediation that stressed overtly the correct direction for word and line scanning was suggested to overcome this problem if it persisted. Gates was especially strong in insisting on left-to-right processing of words, railing against overemphasis on word endings. He failed to recognize, however, that overemphasis on word beginnings could lead to guessing at words based on first letters, a phenomenon observed in a number of countries.

Monroe and Robinson. Among other important studies on reading disability, the work of Monroe (1932) and Robinson (1946) was nearly as influential as that of Gates. Monroe worked on reading disability at the University of Iowa in the

1920s where she came in contact with Orton and his ideas about mirror-reading and mirror-writing. Although tests for these phenomena were included in the test batteries she developed there and later at the Illinois Institute for Juvenile Research, the hemispheric dominance component of Orton's theory was not a major factor in her work (Monroe, 1928). Monroe (1932) reported on measures of reading disability among 415 children, ranging from the mentally retarded to the intellectually gifted, and a control group of 101 average school children. The experimental subjects varied in age from about 6 to 17, and the controls varied from about 6 to 11. The range of quantitative and qualitative tests given to each student included reading and mathematics achievement, oral reading errors, intelligence, hand- and eye-preference, mirror-reading and mirror-writing, handwriting, speech and auditory discrimination, and sound blending.

Results from the visual processing measurements showed a significantly greater percentage of left-eye preference and left-eye preference with right-hand preference within the reading disability groups than among the controls. Left-eye preference was associated with fluent mirror reading, which in turn was associated with reading disability. In contrast, reversal errors in reading did not differ significantly according to eye preference. The first general conclusion drawn across the full battery of tests was that no single factor was represented in all of the remedial cases and each factor that helped differentiate the remedials from the controls could be found in a contradictory case. "It is probable that the reading defect is caused by a constellation of factors rather than by one isolating factor. Two children may therefore possess much the same impeding constitutional factor and yet one, through good environmental, methodological, and emotional factors, may overcome the disability, while the other, through poor environmental, methodological, and emotional factors, may become seriously retarded" (p. 110).

Robinson (1946) both reviewed the literature on reading disability and reported on analyses of 30 seriously retarded readers who ranged in age from 6 years 9 months to 15 years 3 months. All had IQs of at least 85 (New Stanford-Binet Intelligence Test, Form L) and each was examined by a battery of specialists, including a social worker, psychiatrist, pediatrician, neurologist, ophthalmologist, speech-correctionist, a reading specialist, and a few others. Besides achievement tests for reading, each child was tested for eye, hand, foot, and ear preference. (The other tests, covering vision, skull X-ray, hearing, etc. are not of direct interest here.) After testing, a remedial plan for each child was developed, but not all of the cases were treated by the investigator. Six of the 30 cases were judged by the neurologist to have indications of problems that could interfere with learning to read. One of these cases responded very quickly to remedial-reading training, two responded very slowly, and two were not treated.

Results from the preference tests showed a 93% agreement between hand and foot preference but only 73% agreement between hand and eye. No relationship

was established, however, between eye and hand preference agreement and degree of reading disability.

The general results were similar to those found by Monroe (1932), that is, that multiple factors were usually involved in reading disability. Readers who were severely retarded in reading tended to have more anomalies than those who were less retarded, but the pattern of anomalies varied from reader to reader. Visual anomalies were the most prevalent, occurring in 73% of the cases. Social and emotional maladjustments were next in frequency of occurrence.

CONCLUSIONS

A search across the history of writing failed to find, prior to the introduction of printing, any significant attention to visual processing needs in the evolution of writing systems. Accelerating the output of the scribe/writer and minimizing the number of sheets of papyrus, parchment, or paper required for a document appeared to have been far more important than the travails of the reader. Exceptions did occur, as in the insertion of chapter titles, the slow evolution of punctuation, and perhaps even in the various changes that occurred beginning in the 13th century to break up sequences of minims.

To some degree this neglect of the reader can be explained by the limited number of literate people during the eras of interest, and by the role of reading at these times. Until the Renaissance, literacy was generally limited to clerics, administrators, and some members of the aristocracy. Although the percentage of literates varied considerably across and within countries throughout the history of writing, the idea of mass literacy, promulgated nationally, emerges only in the 19th century. Reading was primarily an oral activity and it served mainly bureaucratic and religious ends. When the appearance of the manuscript page was attended to, the goal was primarily to impress and to awe, not to enhance verbal communication. Without a mass market for print and without a common need to consume large amounts of print daily, there was little pressure on scribes or printers to produce more readable documents. Until a market occurred, competition in the production of print products was limited, and therefore the reader could not exercise a preference for more readable materials over less readable ones.

Almost no research is done on the nature of reading in earlier periods, yet this field could be explored through imitative experiments. It would, for example, be possible to do training and testing on the reading of medieval scripts, using letter search as well as other paradigms. Similarly, evidence may be available for estimating the total amount of reading that an administrator, shop owner, or trader might do during a week of work. Using data that could be obtained from studies of adult literacy, we might be able to estimate expected reading speed and

possibly even degree of subvocalization in reading from earlier periods. At a minimum, legibility studies could be done of manuscript forms and of the fonts from the early period of movable type printing.

The end of the 18th century marks the beginning of the experimental study of visual factors in reading. These earliest studies, however, were totally atheoretical, as most legibility studies have tended to be since that time. With the emergence of experimental psychology in the last quarter of the 19th century, a knowledge base for studying the visual aspects of reading rapidly emerged. Equally importantly, reading was studied within a more general theoretical framework that was constructed around the speed of mental events and around perceptual processing in general. Within a period of about three decades, almost all of the visual processing problems that capture our attention today were observed and explored. Although we have far better equipment today for studying visual processing and we know far more about experimental procedures, we still return with unbridled nostalgia to Huey (1908) and the psychological milieu that he wrote about.

In doing so, we risk inflating the degree of insight and discovery that occurred then. Most experimenters prior to World War I had limited knowledge of perceptual development or of learning in general. Results from adult studies were assumed to be relevant to the instruction of the young. Except for a few experimenters like Hamilton, no one acknowledged the ability of the reader to control recognition strategies. Subjects for many studies were recruited from one's own faculty colleagues or advisors, and often from those who knew the purpose of the study and who may even have assisted in its design.

Oral report was often employed in the early studies of perception in reading, so confounding of perception and memory was frequent. Until the partial report paradigm was introduced, these factors were seldom separated. Other paradigms unknown before World War II, such as priming and the lexical decision task, have also contributed to an understanding of word recognition processing that extends far beyond what was known to Cattell or to Dodge or to Dearborn. Then, factors such as letter and word frequency and orthographic structure were poorly understood and seldom either explored or controlled in experiments. Models for visual processing were crude, at best, with limited or no appreciation of the different types of memory involved and the possibility of recoding for retention in short-term memory.

Yet even with these reservations, it is difficult to ignore the enormous progress that was made prior to World War I in understanding visual processes in reading. That we still are trying to understand how printed words are recognized, and why particular letters are often confused, and whether certain reading disabilities have a neurological basis do not mean that little was accomplished prior to the present time. Many of the old problems are still with us, as the remaining chapters of this book demonstrate, but we stand on higher ground in attacking them, thanks to what has been learned in the past.

More could be said on this topic and much of what has been said could be more tightly organized and more closely related to trends in psychology and education. Paradigms change, as Kuhn (1970) made us so aware, and many problems once thought to be pivotal to our continued existence are abandoned while formerly unnoticed issues become national concerns. With the current emphasis in reading research on assessment and on comprehension and higher level thinking, few major new research programs on word recognition will be started and no research and development center will be dedicated to this issue. Perhaps a knowledge of the rich history of interest in the visual component of reading and of the problems that remain will lead a few researchers to explore this arena.

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