1 Toward a grounded synthesis of mind, brain, and education for reading disorders: an introduction to the field and this book

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This is a new era in the fields of education, neuroscience, and cognitive science—the time to bring together mind, brain, and education. The advent of powerful new in vivo brain imaging technologies, the power of the burgeoning discoveries in genetics, and the general excitement in society about biology make possible a new alliance relating biology, cognition, and education (Educational Leadership, 1998). Hidden brain and genetic processes are becoming increasingly visible (Gage, 2003; Lyon & Rumsey, 1996; Thatcher, Lyon, Rumsey, & Krasnegor, 1996), and in a few tantalizing cases, researchers and educators can even begin to observe the functional neuropsychological effects of educational interventions. It is an exciting time! This book is designed to promote the dialogue that is essential to creating the best integration of biology, cognitive science, and education.

The burgeoning new knowledge and the focus of society on biology lead to expectations that sometimes upset the balance between scientific knowledge and meaningful use in practice, raising numerous new ethical and educational issues (Battro, 2000; Bruer, 1997, 1999; Scientific American, 2003). The best research and the best educational practice require a two-way interaction between the scientific research and the knowledge of educators working to help children learn. Research in neuroscience and genetics, for instance, gains new significance and controversy as educators and clinicians work to translate it into practice, dealing with the strengths and weaknesses of real children learning in schools. This translation to practice should, in turn, filter back down to shape new scientific questions. In this era of translation across disciplines, no longer can neuroscience and cognitive science research remain in the ivory tower, and no longer can educational practice escape scientific scrutiny (Shonkoff & Phillips, 2000; Snow, Burns, & Griffin, 1998). Each discipline has so much to learn from the other!
Connecting mind, brain, and education

As educators, cognitive scientists, and neuroscientists, we have a responsibility to children to establish and maintain dialogue among our respective fields. To be maximally productive, this dialogue must go both ways. New information about the development and functioning of the brain awaits interpretation and practical application in the classroom, while educational input and practical insights are essential in shaping new brain research. Indeed, the disciplines of education and neuropsychology are growing increasingly interdependent, and like the cousins from the country and the city, scientists cannot carry out good research, nor can educators carry out good practice, without interweaving these perspectives.

Society has high expectations, perhaps unrealistic ones, about the benefits of bringing biology into education. Scientists and educators are clamoring to make the connections in many ways, some of which will be productive and some of which may be disastrous (Bailey, Brue, Symons, & Lichtman, 2001; Brue, 1999). One important trap to be avoided is the assumption that laboratory science by itself will provide answers that can then be applied to education. A productive relation of education, biology, and cognitive science does not start in the laboratory, with direct application of scientific findings to classrooms and students.

What is required instead is a reciprocal process in which education informs biological research as much as biology informs educational research and practice (Battro, 2000; Gardner, 1983). The process should be similar to that in medicine, where medical practice informs biological research as much as biology informs medical practice. In education, reading a textbook is distant from reading a string of words in a reaction time study in a laboratory that measures brain activity with functional magnetic resonance imaging (fMRI). Results from such a different laboratory context seldom apply felicitously to the classroom. That is why so much laboratory research has failed when scientists have attempted to apply it to education.

Educational settings and tasks are essential for useful research in mind, brain, and education, just as medical settings and tasks are essential for useful research in biology and medicine. Laboratory research plays an important role in analyzing fundamental processes, but research in the settings of practice is key, and it is needed right now! Some scientists believe that it is premature to relate biology to education, that education needs to wait for scientific breakthroughs that solve the deep questions of mind and brain. We believe instead that research from education will help to shape the breakthroughs of the future by informing basic biological and cognitive research about human learning and behavior in schools and homes where children develop and learn.

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How do educational interventions affect processing in the brain, and how can curricula be designed to make optimal use of developmental plasticity? Conversely, what are the educational implications of neuropsychological findings about processing of language and text, and how should these implications inform educational research and practice? To begin to address these and related questions, we must move into an era of partnership of education with neuroscience and cognitive science, in which we examine and treat educationally relevant capacities and skills from both perspectives.

In the service of promoting optimal connections of mind, brain, and education, this book is meant for neuroscientists, cognitive scientists, and educators alike. Although readers will undoubtedly be drawn initially to the chapters by their disciplinary colleagues, we urge you to delve into the chapters representing approaches other than your own. We hope that you will be inspired to many productive and innovative discussions that challenge assumptions and make connections across the fields of biology, cognitive science, and education.

Reading and learning disorder

Toward these goals, this book is conceived as a first attempt to systematically bring together the latest neuropsychological, genetic, and educational perspectives on a cognitive skill that is of central importance in both the neurosciences and education: reading. Reading is an excellent place to begin this interdisciplinary dialogue. Long traditions of cognitive neuroscience research have attempted to pin down the component processes of reading and reading problems (Benes & Paré-Blagoev; Galaburda & Sherman; Immordino-Yang & Deacon; and Paré-Blagoev, this volume). Simultaneously, long traditions of educational research and practice have analyzed literacy instruction and interventions for teaching reading and helping students with reading difficulties (Snow et al., 1998; Case; and Wolf & Ashby, this volume).

Reading has been studied in far greater detail than any other area of academic competence, and reading disorders provide the most extensive, detailed, and methodologically sophisticated research literature of any learning disorder. For all these reasons and because literacy is so fundamental to our society, reading provides an ideal common focus for researchers and practitioners from diverse disciplines and perspectives to examine the interface of mind, brain, and education.

The book deals not only with reading, but it focuses especially on learning disorders. Following the long localization tradition in neuroscience, scientists and educators look to atypical as much as to typical functioning to infer the component processes and developmental principles involved in reading (Geschwind, 1965; Huttenlocher, 2002; Neville & Bavelier, 1998; Pennington,
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What is the ontogeny of the sculpted functional neural networks seen in adults? Contemporary neuroscience has yet to tell what will be a fascinating story, which will ultimately be one of the most fruitful tools for applying the emergent neuroimaging technologies. How does the modularity that is characteristic of brain–behavior relations in adults develop in children, where modularity is not so evident? In children individual skills or components of skills emerge from more global developmental frameworks, within which boundaries can be initially indistinct, emerging over time.

Understanding the principles that govern localization processes in children and adults requires a concurrent educational analysis of children’s evolving skill profiles in relation to the cognitive experiences created by reading instruction. This requirement underscores the essential contribution of an educational perspective to the neuropsychological study of reading disorders. While the methods of neuroimaging necessitate a focus on deficits in individual component processes, educational methods can contribute the dynamic, in situ analyses that reveal the bigger picture (Campione; Fink; Fischer, Rose, & Rose; D. Rose, this volume).

Thus the second theme of the book is more pragmatic — the feedback of neuroscientific and behavioral findings into educational policy and practice. At the neuropsychological level, what are learning disorders, and who has them? What neuropsychological strengths might be used to remediate weaknesses? At the educational level, what should be done for those with reading disorders in terms of assessment, instruction, and motivational techniques, and how can we characterize a successful outcome? What does a diagnosis of learning disorder mean for the broader context of a person’s life?

In thinking about these questions from an interdisciplinary perspective, we come to understand reading disorder as but one manifestation of a neuropsychological profile that often can underlie difficulties in multiple domains of developmental adaptation, such as communication, social skills, and organization of goal-directed behavior (Bernstein; Case; D. Rose, this volume).

Plasticity and constraint

In the book these themes play out in the dynamic tension between plasticity and constraint in brain–behavior relations, especially in children. The structural properties of the configuration of neural networks and systems will constrain the plasticity with which children develop reading abilities and overcome reading disorders. There are no isomorphic relations between unitary structures and functions, but instead there are architectural constraints, governing the neural configuration that gives rise to behaviors and skills in a learning environment. The skills of reading, which have no evolutionary precedent to ground them firmly in neuroanatomy, are distributed within the complex networks of systems.
that make up the systems for visual and oral language and comprehension (Immordino-Yang & Deacon, this volume).

A striking consistency is becoming apparent between modern functional neuroimaging studies (PET (positron emission tomography), fMRI) and the inferences drawn from years of neuropsychological observation of individuals with focal lesions, and so the architecture of language and reading networks is likely to have universal properties (Benes & Paré-Blagoev; Duffy; Paré-Blagoev, this volume; Shaywitz, Shaywitz, Fulbright, Skudlarski, Mencl, Constable et al., 2003). However, the greatest contribution of the functional neuroimaging studies to date is likely to be the confirmation that mental functions are associated with dynamic neural systems, not static brain regions. For example, recovering victims of brain damage, especially that incurred during infancy and childhood, demonstrate the flexibility of these networks. The interplay between this flexibility and the architectural constraints on network configuration is central to the study of reading disorders.

On a moment to moment basis, the neurological networks involved in reading are recruited in the service of several concurrent behavioral goals. Reading is thus a remarkably complex process, requiring effective timing and integration of multiple networks to be efficient. We suspect that the relatively subtle processing inefficiencies seen in children identified as learning disabled compound into debilitating reading difficulties based on the children having certain kinds of educational experiences and not others. As scientists and practitioners have widening opportunities to apply functional imaging techniques to the problem of reading disorder, the focus will evolve from the current emphasis on specific skill deficits to a dynamic analysis of the functional neural networks used in real-life learning contexts - which will facilitate analysis of the true nature of the disorder.

What are the range and limits of plasticity, and how are they mitigated by experience, such as by different kinds of reading instruction? Learning disorders entail relatively subtle individual variations in efficiency and efficacy of various cognitive functions. Not only their source but most especially their potential for change in response to interventions are uncertain. Moreover, the relative balance between the child's development (Bailey et al., 2001; Neville & Boder, 2001; Newman, Bavelier, Corina, Jezzard, & Neville, 2001; Case; Fischer, Rose, & Rose, this volume). These issues of plasticity and constraint cut to the heart not only of our appraisal of the scientific evidence about structure-function relations, but equally importantly to our ethical beliefs about human potential and rights of the individual. To what extent should the goal of intervention for children with learning disorders be normalization of performance, and to what extent should it be helping the child to identify and prepare for a niche within which he or she can be productive and experience success? What can we reasonably expect the educational system to provide?

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In the arena of these very pragmatic questions, advocates of plasticity and constraint have often collided, and there is no one obviously correct resolution of this tension.

The issues that this book addresses are not the easy ones for which answers come in black and white, but the difficult ones that reside at the boundary where plasticity and constraint meet practical educational considerations. This is one reason that we invited several neuroscientists to contribute, including some with no special expertise on learning disorders - to help frame the broad questions that need to be asked about brain, development, and learning. Some of them have contributed chapters, and some have written shorter essays to describe a relevant topic, such as brain growth cycles or the effects of traumatic experience on the brain. Effective framing of questions about brain bases of learning disorders requires dealing with questions of brain growth patterns, brain bases of language, the role of experience in shaping brain development, and genetics. After all, the ultimate goal of this interdisciplinary discussion is to tease apart the effects of experience, anatomy, and genetics on functional brain organization, to relate these principles to the case of reading, and to think about what the patterns of findings all mean for a real, developing child.

Conceptual organization of the book

In accordance with these themes and goals, the book connects mind, brain, and education throughout, although some chapters contribute more heavily to one or the other aspect. The book moves from the biological foundations of reading in Part I through developmental analyses of mind, brain, and education for reading and learning disorders in Part II to analyses of individual children's skill patterns in Part III. It concludes by placing reading and learning disorders in the broader context of society and lifelong development in Part IV.

The biology of reading

The first section of the book works to define the phenomena of reading disorder by placing the brain bases of reading development into a broadly biological perspective, including neuroscience, evolution, and genetics. The second and third chapters focus especially on the biological constraints of species and genes that are built into the neuropsychological capacities required for reading. The Immordino-Yang and Deacon chapter lays out a nested model of reading-related skills for understanding the relations between genes, brain functions, and behaviors. It also cautions against the search for one-to-one correspondences between genes and complex cognitive pursuits like reading. In the essay embedded in the chapter, Caviness describes the newly emerging study of brain volume in living brains, because differences in brain volume play a prominent
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In the third section of the book, theory is brought into practice, as neuro-physicists and educators in turn present their assessments and understandings of four boys’ reading and related behaviors. (Transcripts of the boys’ testing sessions can be found in the Appendix.) While the chapters in the second section focus on the cognitive skills and brain processes relevant to reading, the chapters in this section work from the videos of four boys to define and debate how their skills actually present in real-life learning contexts. Bernstein provides a broad framework for neuropsychological analysis of learning differences and disorders in these and other children, underscoring the necessity of analyzing children’s interactions and contexts as well as their performance on standardized measures. Brady suggests that better understanding of dyslexic children requires fuller analysis of the relations between written and oral language skills and of the fit between neuropsychological analyses and educational practices. Blachman and Torgesen both discuss a need to better understand how different neuropsychological skills manifest and interact in different educational contexts, with Blachman focusing on fluency of reading while Torgesen emphasizes the need to understand secondary deficits such as comprehension. Taylor emphasizes the relation between environmental and neurological influences, suggesting a bottom-up approach in which low-level cognitive weaknesses reveal a profile of core deficits with implications for education.

Reading skills in life

In the final section of the book, the authors emphasize long-term trajectories for reading and learning problems, broad issues of reading in schools and society, and implications for educational practice. Theory and practice from neuropsychology and education come together with a unique goal in mind— to bring life-span and societal issues to bear on the neuropsychological and educational
debates about the nature and process of reading. Coming full circle back to Immordino-Yang and Deacon (Chapter 2), Campione emphasizes that in the search for the low-level neuropsychological causes of dyslexia, researchers and educators lose sight of the most immediate, important, high-level repercussions for children—reading comprehension problems and lack of access to printed ideas and information. Because this lack of access is a problem not only for true dyslexics but for any population of children with poor reading skills, future research should investigate the similarities and differences between dyslexics and other populations whose reading is poor, such as many poor urban and rural schoolchildren.

Fink describes another important group, people who have dyslexic difficulties but can nevertheless read and comprehend with great skill. She studied highly successful dyslexic adults who had difficulty learning to read in the early school years. Even with continuing difficulties with decoding words, many people become excellent readers, motivated by a passion for learning about topics that especially interest them. Such affective and strategic aspects of learning to read are certainly as important as decoding and are essential to successful compensation for dyslexic problems.

This emphasis on the diversity of reading problems and skills highlights difficulties with the term learning disability, which embodies some of the unfortunate consequences of society’s practical use of a concept that has become imprecise in scientific research. In this book, we editors have deliberately avoided using the term, choosing instead to speak of learning disorder. Learning disabilities are often assumed to involve a discrete and identifiable set of children, typically assessed by a measured gap between intelligence-test scores and learning performance. Political and legal ways of defining services for them are usually based on practical concerns rather than scientific evidence (Snow et al., 1998; Stuebing, Fletcher, LeDoux, Lyon, Shaywitz, & Shaywitz, 2002; Bernstein; Torgesen; Wolf & Ashby, this volume).

There has emerged a troubling disconnection between the scientific community and the educational gatekeepers, who must make the difficult decisions about allocation of finite resources to the most deserving children. Equally complicated is the implementation of legislative mandates such as the Americans with Disabilities Act. The scientific goal is to ascertain how to decide who does and does not merit this diagnosis, in a reliable and valid fashion, unconstrained by pragmatic limitations. Because of these real-world exigencies, diagnostic classifications are made routinely, with significant institutional consequences, even though scientists may be well aware of the tenuous nature of some of these decisions.

This conundrum must also affect the dialogue in this book: how are scientists and practitioners to discuss a diagnostic entity when they cannot reliably agree on what it is or who has it? The term disorder is invoked as an attempt to sidestep this issue, to call attention to the ambiguity, and to emphasize that at the present time it refers to a fuzzy set of individuals.

Building on the social problems and practical difficulties created by work on learning disabilities, David Rose warns us against overly constraining our research on reading skills associated only with print, as we would surely be misrepresenting the problem and missing important opportunities to engage children with information in other formats. That is, reading skills are rarely the only set of skills that differentiate dyslexics; there are usually also social and physical correlates of dyslexia, as well as a characteristic set of relative strengths. In addition, overly focusing on remedial decoding would mean ignoring the affective and strategic aspects that, writes Fink, are often a major part of successful compensation.

**Conclusion: reading and learning disorders**

To conclude, learning disorders must be viewed as a set of relatively subtle phenomena in a range of developmental neurobehavioral syndromes that include more dramatic disorders such as mental retardation, schizophrenia, and autism. Not only is a learning disorder subtle, but it engages social and affective considerations and debate to a far greater degree than the more dramatic, less subtle disorders, because the boundaries, definitions, and causes are less clear. With a view to helping clarify this edges, the book triangulates converging neuroscientific, cognitive, developmental, clinical, and educational perspectives on the study of learning disorders, focusing on reading. This triangulation helps to define the areas of inquiry and debate that are most current and likely to be most fruitful.

The book ranges far, from neuropsychological and educational analyses of specific cases of boys performing standardized assessment tasks of reading and related skills to cognitive scientists seeking relations between developmental processes and reading to neuroscientists describing how neural networks grow in cycles, how genetics and evolution shape reading, and how neuroanatomical development relates to brain functioning and learning experience. Within and between the main arguments, themes, and debates in the book, we hope to provide some insight into the question of why learning disorders have been so hard to pin down, why interdisciplinary discussions are so essential, and what the future holds for mind, brain, and education. We hope too that you will find your mind to be fertilized by new sets of questions and novel perspectives on learning disorders, and maybe even some productive perplexities. In our judgment, that will mark this book as a success.
REFERENCES


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