The Current State Of Science And The Future Of Specific Reading Disabilities

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Of all the learning disabilities, reading disabilities have the richest clinical and experimental history. Many sources provide fine-grained analyses of historical and current studies of reading disabilities, including their clinical presentation [Wiederholt, 1974; Liberman, 1989; Shankweiler and Liberman, 1989; Adams, 1990; Doris, 1993], definition and classification [Fletcher and Morris, 1986; Hooper and Willis, 1989; Morris, 1993; Lyon, 1995a, 1995b], neurobiological foundations [Duane, 1991; Duane and Gray, 1991, Hynd et al., 1991; Rumsey, in press], genetic etiology [DeFries and GLWS, 1991; DeFries et al., 1991, and response to treatment [Lyon, 1985a, b; Berninger, 1994; Berninger and Abbot, 1994; Torgesen et al., 1992]. These sources should be consulted for a more comprehensive review of the issues we will discuss here. Readers will note that the terms reading disability and dyslexia are both used in this paper. For the purposes of the discussion, both terms refer to significant deficits in the decoding and recognition of single words [see Lyon, 1995a for a rationale for this criterion].

AMBIGUOUS DEFINITIONS AND THE STATE OF THE SCIENCE IN READING DISABILITY

Despite long-standing recognition of reading disorder as a clinical entity that has significant deleterious effects on children and adults, converging empirical support for reading disability as a valid diagnostic concept has been slow to emerge. The difficulty in establishing a strong empirical scientific base for reading disability can be primarily attributed to the field's recalcitrance in establishing an objective, inclusionary definition and classification system for the disorder [Fletcher and Morris, 1986; Lyon. 1995a, 1995b]. Why is an objective, inclusionary definition so important, and how has the scientific status of the field been hindered in its absence?

As we have pointed out elsewhere [Lyon, 1995a], a precise and inclusionary definition is critical for at least three reasons. First, accurate identification of reading disability requires that the key symptoms and characteristics be specified. Second, treatment of reading disability, including early intervention and general teaching methods, must be based on an informed understanding of the difficulties that impede reading development and mastery for children and adults with the disorder. Third, an operational definition is essential for research purposes. More specifically, without the well-defined subject selection criteria that an operational definition provides, research examining the causes and consequences of reading disability, the existence of different types of the disorder, and the responses of affected individuals to different forms of treatment typically can not be interpreted, replicated, and generalized. From an applied perspective, vague definitions result in capricious clinical decision-making. For example, when definitional criteria are ambiguous and unsupported by research findings, the basis for assigning support services are unclear and numerous inequities exist with respect to who does and does not receive special education. Traditional definitions of reading disability have contributed to the loose conceptual and theoretical thinking about dyslexia.

Historically, early definitions of reading disability or dyslexia have been exclusionary [see Fletcher and Morris, 1986]. Within this context, reading disability is identified if the difficulty in reading exists in the absence of other problems (e.g., mental retardation or sociocultural deprivation) that could lead to it. As Putter [1978] pointed out, an exclusionary definition ". . . not only fails to add conceptual clarity, but also implies that dyslexia (or reading disability) cannot be diagnosed in a child from a poor or

unconventional background. In short, it suggests that if all the known causes of reading disability can be ruled out, the unknown (in the form of dyslexia) should be invoked" (P. 42).

In addition, many early definitions such as those advocated by the United States Office of Education (USOE 1977), cast the identification of reading disability into the broader category of learning disabilities. As Stanovich [1993] has argued, attempting to define reading disability via the general characteristics set out for the extremely heterogeneous category of learning disabilities will result in vague and ambiguous criteria for subject selection---a process guaranteed to obscure any legitimate scientific discovery about the reading process. It should also be stressed that a number of classification scientists [Fletcher et al., 1993; Lyon, 1995a, 1995b] have pointed out that even domain-specific definitions of reading disability such as those developed for the DSM-IV [APA, 1994] and the ICD-10 Classification of Mental and Behavioral Disorders [World Health Organization, 1993] continue to embody vague criteria that are difficult to operationalize. In addition, these definitions continue to recommend the use of IQ-reading achievement discrepancy data in the diagnostic process--a recommendation that recent research suggests is invalid.

Another issue that has confounded scientific progress in reading disability relates to measurement practices designed to operationalize the construct of unexpected underachievement that is inherent in most definitions of reading disability. Unexpected underachievement in reading simply refers to the notion that deficits in reading are hypothesized to be unexpected, and thus can not be predicted by, a child's age, intelligence, other academic abilities, exposure to instruction, or socio-cultural opportunities. Typically, IQ-reading achievement discrepancy formulas have been employed to provide an objective analysis of the degree of relationship between individuals' general cognitive ability (i.e., IQ) and their reading performance. The more disparate the two scores, the greater the degree of unexpected underachievement.

For at least two major reasons, an IQ-reading achievement discrepancy is an inappropriate and invalid marker for reading disability. First, it is not clear how IQ-achievement discrepancies are to be operationalized and defined (Lyon, 1987, 1988; Aaron, 1989; Share et al., 1989; Zigmond, 1993]. For example, which IQ score and which IQ measure should be employed? Is the Full Scale IQ the most appropriate metric, or should the Verbal or Performance IQ be used as the measure of aptitude or potential ability to read? In addition, which statistical calculation should be used to derive the degree of unexpected under-achievement? Should a difference between IQ and achievement standard (Z) scores be employed or should one apply a formula that derives the difference between expected and actual achievement levels based on the regression of IQ and achievements?

Although these psychometric issues are debated, the second and more important question is whether IQ-achievement discrepancies, no matter how they are measured, tell us anything about reading disability. Apparently they do not. If one defines reading disability as deficits in decoding and recognizing single words, a discrepancy between IQ and reading achievement appears to be an invalid marker. Specifically, children with reading disability who have high IQ scores (discrepant poor readers) do not differ from children with reading disability who have lower intellectual aptitudes (nondiscrepant poor readers) on measures assessing decoding and word recognition skills [Olson et al., 1989; Siegel, 1989; Fletcher, 1992; Fletcher et al., 1994, Francis et al., 1994], phonological skills [Fletcher et al., 1994; Stanovich & Siegel, 1994; Shankweiler et al., 1995], genetic characteristics (Pennington et al., 1992; Pennington, 1995], or neurological characteristics [Stanovich and Siegel, 1994]. Simply put, reading disability involving deficits in reading single words is not correlated in any way with IQ discrepancy. This lack of validity demonstrated for IQ-reading achievement discrepancies does not, at least at this point, obviate the conceptual notion that the reading deficits observed in children with reading disability can be characterized as unexpected. As Stanovich [1991] has pointed out, the critical task will be to identify the most valid predictor of an individual's potential to read at the single-word level. Thus, it is quite possible that reading disability may be characterized by poor decoding and word recognition against a

background of other cognitive and academic strengths (e.g., listening comprehension), but not expressed as an IQ-reading achievement discrepancy. Clearly, the state of science in reading disability will be advanced if the issue of unexpected underachievement is clarified.

SCIENTIFIC PROGRESS AND MOMENTUM IN READING DISABILITY

With the increasing recognition that studies on children identified as having reading disability via exclusionary definitions typically lead to difficulties in replicating results, more recent research efforts have begun to investigate reading difficulties in well-defined samples, within the context of prospective, longitudinal designs. In contrast to studies of children in schools and clinics who previously were defined as having reading disability on the basis of inconsistent definitional and diagnostic criteria (i.e., using IQ-reading achievement discrepancies), investigations based on prospective, longitudinal designs can provide an opportunity for the same children to be initially studied as they enter the first grade and then repeatedly observed over time. Thus, there is no need for *a priori* assumptions about what reading disability is, particularly if children are initially identified during preschool or the first grade, then studied for several years within a wide range of cognitive, linguistic, neurobiological, and genetic contexts. In essence, this type of design allows the researcher to test hypotheses about which classification and definitional criteria are the most valid. Prospective, longitudinal studies of reading disability can therefore serve as a research platform to attain a number of goals, including identification of critical cognitive, academic, and behavioral diagnostic characteristics that may be manifested in different ways at different developmental periods: identification of neurobiological and genetic features that predict reading disability; development of valid early predictors of achievement and under-achievement in such components or reading as decoding, word recognition, and comprehension, mapping of the developmental course of reading disability; identification of comorbidities and secondary behavioral consequences that develop in response to reading disability and assessment of the efficacy of different treatment and intervention methods.

During the past decade, the National Institute of Child Health and Human Development (NICHD) within the National Institutes of Health (NIH) has undertaken a substantial effort to conduct longitudinal research to achieve these goals. Specifically, in addition to a comprehensive 30-year NICHD study of language and reading ability / disability underway since 1966 at the Haskins Laboratory, the NICHD supports Learning Disability Research Centers at Yale University, the University of Colorado, and Johns Hopkins University; Dyslexia Research Projects at the Bowman Gray School of Medicine, Yale University, the University of Colorado, and Beth, Israel Hospital / Harvard University; and Reading Disability Treatment / Intervention Research Projects at Florida State University and the University of Houston, Additional Learning Disability Research Centers at the University of Washington, Seattle, and Children's Hospital in Boston (Harvard) came on line in December 1995.

The comprehensive multidisciplinary longitudinal investigations undertaken at these sites (with the exception of those at Beth Israel, which are animal studies) have obtained converging data indicating that deficits in phonological processing reflect a core cognitive deficit in reading disability; that illuminate the neurobiological and genetic underpinnings of phonological deficits; that provide a map of the developmental trajectory of reading disability; and that show, for the first time, how different treatments can alter the course of the disorder [see Lyon, 1995b].

Thus, a science of reading disability is emerging that has its roots in both biology and behavior and that uses the expertise of cognitive neuroscientists, linguists, neurologists, pediatricians, neuropsychologists, radiologists, and educators.

READING DISABILITY IS A LANGUAGE--BASED DISORDER

Data derived from a substantial number of well-designed studies indicates that reading disability typically reflects insufficient phonological processing abilities [Liberman and Shankweiler, 1985; Adams, 1990; Brady & Shankweiler, 1991; Liberman, 1992; Stanovich, 1993; Fletcher et al., 1994; Share and Stanovich, 1995].

A phoneme is the smallest unit of functional sound. Our apprehension of these segments within running speech is made possible by our ability to process phonological information within our brains. Phonological processing has been conceptualized as encompassing at least three different components or skills: phonological awareness, typically assessed by phoneme deletion and rhyming tasks: phonological recoding in lexical access, which can be assessed by rapid naming tasks; and phonetic recoding in working memory, which can be measured by digit- and word-span tasks [for reviews, see Wagner & Torgesen, 1987; Adams, 1990],

Of these three major phonological processing skills, phonological awareness appears to be the most deficient language skill in disabled readers. In a practical sense, phonological awareness is essential in enabling children to map, or translate, printed symbols (letters and letter patterns) to sound. If children cannot perceive the sounds in spoken words---for example, if they cannot "hear" the "at" sound in "fat" and "cat" and *(they cannot)* perceive that the difference between these sound segments lies in the first sound, they will have difficulty decoding words accurately and fluently [Beck and Juel, 1995]. *(emphasis added)*

From an empirical standpoint, there is a wealth of evidence that deficits in phonological awareness not only co-occur with deficits in basic reading [Vellutino and Scanlon, 1987; Pratt and Brady, 1988], but that the relationship is, in fact, a causal one, with deficits in phonological awareness impeding the acquisition of reading skills [Wagner and Torgesen, 1987; Cairs, 1989; Brady and Shankweiler, 1991; Stanovich, 1993; Olson et al., 1994; Torgesen, 1996]. Indeed, the nature of the English orthography and its alphabetic characteristics rely on this linguistic ability, which allows the reader to segment words into their constituent phonemes. The beginning reader must be conscious of the sound segments in syllables and words and must be able to manipulate them on demand. Such awareness is critical if one wishes to rhyme words, speak in "pig-Latin," segment words into syllables and syllables into sounds, and most importantly, to decode and recognize words accurately, automatically, and fluently. Simply put, limitations in phonological awareness lead to slow, labored, and inaccurate decoding of words, which, in turn, leads to poor reading comprehension [Lyon, 1995a].

Additional candidate linguistic and visual processes have been implicated in reading literacy. For example, Wolf and her associates [Wolf et al., 1986; Wolf, 1986, 1991] have argued that reading deficits can also be caused by visual naming-speed deficits, or impairments in precise timing processes underlying rapid retrieval of names for visual symbols. According to Bowers and Wolf [1993], children with both visual naming speed deficits and phonological deficits are the poorest readers, but children with either deficit alone are significantly less capable in reading than are youngsters who are phonologically adept and rapid namers.

In another line of research, Tallal and her associates [Tallal and Piercy, 1973; Tallal, 1980, 1988] have suggested that the same verbal and nonverbal temporal processing deficits that appear to impede linguistic development in children with language impairment may also be responsible for the reading deficits of children with reading disability. However, we refer readers to Studdert-Kennedy and Mody [in press] for an explanation of some of the difficulties with this research. In short, Studdert-Kennedy and Mody argue that Tallal's interpretation of the data indicating temporal processing deficits in children with reading disability may be confounded by the fact that the children are having difficulty

discriminating highly similar tonal and syllabic stimuli rather than difficulties judging their temporal order.

Another potential challenge to a strictly phonological account of reading disability derives from Scarborough's [1990] longitudinal research, which showed that children who would manifest reading deficits by the second grade could be distinguished from their normal-reading age-mates at 30 months of age on a variety of language tasks that assessed, among other abilities, sentence length, semantic knowledge, and syntactical and grammatical complexity. Scarborough's findings suggest that reading disability may be related to a broader language based deficit that exceeds the boundaries of a specific phonological core deficit. In addition, Lovegrove and his associates [Lovegrove et a1., 1987; Martin and Lovegrove, 1988] have adduced data suggesting that a subgroup of children with reading disability read poorly because of deficiencies in rapid visual orthographic processing. These data remain controversial [Vellutino et al., 1994]. Also, the causal linkages between the visual processing deficits and reading disability that Lovegrove described have not yet been firmly established [Hulme, 1988].

Although deficits in visual naming speed, temporal processing, semantic development, syntactic processing, and visual orthographic skills may ultimately be found to exert some independent influences on the developmental reading process, the current evidence remains no more than suggestive. Specifically, the precise role of these deficits, outside of their association with phonology, is not clearly understood [Lyon, 1995a]. At this time, taken together, the data derived from the longitudinal investigations of reading disability strongly indicate that deficits in phonological awareness constitute the major impediment to learning to read. (emphasis added) But how do deficits in phonological awareness interfere with the reading process?

THE SINGLE WORD AS THE CRITICAL UNIT OF ANALYSIS

In essence, reading disability can best be observed as child or adult attempts to read single words, either in list form or in text. As individuals with reading disability read aloud, one typically observes a labored approach to decoding and recognizing single words that is characterized by hesitations, mis-pronunciations, and multiple attempts to "sound out" the word. If asked about the meaning of what they have read, the individuals frequently do not know; most of their cognitive resources have been deployed toward deciphering the words. There is no way to bypass this word-recognition stage of reading, and context is of little help [Adams and Bruck, 1995; Beck and Juel, 1995]. In fact, attempting to use context as a strategy to aid the recognition of unknown words actually hampers rather than helps individuals with reading disability because they allocate even more effort to decoding at the expense of comprehension [Stanovich. 1994]. Memorizing each word in the English language as a whole is impossible, given the sheer number of words. Unless would-be-readers learn to decode and recognize single words rapidly, accurately, and fluently, information will not be easily available to them through print.

This description of reading disabled individuals attempting to read reflects three well-replicated scientific findings. First, although reading is a meaning-driven activity, the key to meaning for proficient readers starts with the immediate and accurate recognition of a single written word [Adams, 1990; Adams and Bruck, 1995; Beck and Juel, 1995]. This finding is one of the most robust in the reading, cognitive, and developmental literature; it has been obtained by research teams in the United States [Felton and Brown, 1989; Olson, et al., 1989; Fletcher et al., 1994; Olson et al., 1994; Vellutino et a1., 1994], Canada (Lovett, 1987; Lovett et al., 1988; Bruck, 1988, 1990, 1992; Siegel, 1989; Stanovich, 1991, 1992, 1993, 1994], Great Britain [Goswami and Bryant, 1990; Snowling, 1990], and New Zealand [Tunmer & Nesdale, 1985; Tunmer and Hoover, 1993]. Although this discovery may appear to be at odds with the argument that reading comprehension is the most salient ability in reading development [Goodman, 1986; Smith, 1971], comprehension depends on the ability to decode and recognize single words rapidly and accurately [see Stanovich, 1994 for an excellent discussion of this point].

Children and adults with reading disability are not impaired in their ability to use contextual clues to aid in word recognition. In fact, children with reading disability consistently have been found to rely more than do skilled readers on the semantic clues available in print to assist them in decoding unknown words [Perfetti, 1985; Bruck, 1990]. Unfortunately, as noted previously, this compensatory device actually impedes the efforts of individuals with reading disability and further reduces speed and automaticity in reading. In short, the locus of difficulty for children with reading disability involves acquisition of the skills necessary to read single words.

Deficits in single word decoding and word recognition reflect the specific impact of the deficits in phonological awareness discussed earlier. Difficulties in understanding that phonological segments can be mapped onto letters and letter patterns are a function of the child not understanding that syllables and words are composed of constituent sounds (phonemes) and that these segments can be parsed according to their acoustic boundaries. For individuals with reading disability, this metalinguistic awareness that words have parts is difficult to understand because the phonemes within syllables and words cannot be heard by the ear [Liberman et al., 1967; Liberman, 1992]. Rather, phonological awareness is made possible by the intact functioning of the brain. In many individuals with reading disability, the brain is not processing specific types of linguistic information in an efficient manner.

THE GENETICS AND NEUROBIOLOGY OF READING DISABILITY

Several papers in this issue address the genetic and neurophysiological substrates of reading disability, but we include a brief overview to emphasize the substantial contributions that behavioral and molecular genetics, neuropsychology, and neuroimaging have made to establishing a science of reading disability. During the past twenty years, a wealth of evidence has been obtained suggesting that reading disability aggregates in families, is heritable, and probably reflects autosomal dominant transmission [see Pennington, 1995, for a comprehensive review]. In addition, recent studies using genetic linkage analyses suggest that there are effects of major genetic loci on the transmission of phonological deficits and subsequent reading problems (Cardon et al., 1994; Pennington, 1995).

The specific mechanisms by which genetic factors operate to predispose someone to reading disability are not yet clear. As Pennington [1995] suggests, it is possible that genetic alterations in dyslexia alter or constrict the range of neural development and, perhaps, produce "hardwired" aberrations in the neural tissue substrate [for examples of the neuroanatomical correlates of reading disability, see Galaburda and Kemper, 1979; Rumsey et al., 1986; Galaburda, 1988, 1991; Hynd et al., 1991; Rumsey et al., in press]. It has been hypothesized that such changes in dynamic neural development can compromise emerging neural systems, typically within the left cerebral hemisphere, which are involved in accessing and interpreting linguistic information. For example, previous and ongoing research suggests that poor phonological processing is associated with atypical cortical activation in the left temporal region, as indicated in studies of regional cerebral blood flow [Wood, 1990; Wood et al., 1991]. A number of recent studies employing positron emission tomography (PET) [Rumsey et al., 1995; Rumsey, in press] suggest that the phonological deficits in reading disability are strongly related to decreased activation of the left temporoparietal and superior temporal cortex. Additional functional neuroimaging work [Shaywitz et al., 1993; Shaywitz et al., in press] has shown that anterior regions of the brain are also activated during the performance of a rhyming or phonological task. These findings are important because they demonstrate the utility and precision of noninvasive functional neuroimaging methods that can be used safely with children.

Given the experimental nature of the current neuroimaging research involving children and adults with reading disability, caution should be exercised in interpreting the results at this time. Nevertheless, the technological explosion in the development of neuroimaging methods and instruments, coupled with improvements in task-activation paradigms bodes favorably for scientific understanding of the neurobiological foundations of reading development and disability. For comprehensive reviews of these

advances, see Lyon and Rumsey [in press], Thatcher et al. [in press], and Krasnegor et al. [in press] for comprehensive recent reviews of these advances.

THE ISSUE OF CO-MORBIDITY

As we have pointed our, converging data have clearly shown that the linguistic abilities causally related to learning to read involve phonology, with deficits in phonological awareness best predicting poor reading behavior at the single-word level (Wagner and Torgesen, 1987; Ball and Blachman, 1991; Torgesen, 1988; Catts, 1989; Juel, 1988; Cunningham, 1990; Kahmi et al., 1990]. It is important to note that phonologically-based reading disability can co-occur with other linguistic/cognitive deficits as well as with attention-deficit disorder (ADD). Within the linguistic domain, it is highly possible that the phonological deficit is also the etiological culprit in the development of abilities in spelling and written expression [Ehri, 1989; Moats, 1994; Fowler and Liberman, 1995]. Specifically, deficits in spelling and writing typically share some of the same core deficiencies in phonology [Lindamood, 1994], as do more general deficits in many levels of oral language [Scarborough, 1990; Johnson, 1994].

In contrast, even though reading disability and ADD frequently co-occur in both referred samples (40% co-morbidity) and nonreferred epidemiological samples (15% co-morbidity) [Shaywitz et al., 1994] the two disorders are distinct and separable. Reading disability is most highly associated with deficits in phonological awareness; the effects of ADD on cognitive functioning are variable, with primary deficits in rote verbal learning and memory and limited association with retrieval and phonological deficits [Wood et al., 1991; Ackerman et al., 1994). Although reading disability and ADD reflect different etiologies, it is clear that ADD exacerbates the severity and cognitive morbidity of reading disability [Wood et al., 1991].

The development of any biological and cognitive science of reading disability requires that distinctions and interrelationships between different types of disorders be identified and clarified. The failure to develop classifications that account for co-morbidity has been an important factor in our persistent difficulties in establishing a reliable and valid definition of reading disability or dyslexia [Fletcher and Morris, 1986: Fletcher et al., 1993]. The state of the science in this regard is rapidly improving.

ADVANCES IN TREATMENT INTERVENTION RESEARCH

The finding that reading disability frequently is related to and, probably, caused by deficits in phonological awareness has provided a strong empirical foundation for the conduct of treatment intervention studies. Because phonological deficits can be identified in kindergarten and first grade [Blachman, 1991], systematic studies of the effects of early interventions can be conducted. Within this context, a number of well-designed longitudinal treatment or intervention studies have been conducted during the past five years by Blachman and her associates [Ball and Blachman, 1991; Blachman, 1991; Blachman et al., 1994], Torgesen and his group [Torgesen et al., 1992, 1994, in press, and Foorman 1995]. **The data from these studies indicates that children with phonological based reading disability require treatment programs composed of direct and explicit instruction in phonemic awareness combined with instruction to develop sound-symbol relationships via synthetic phonics instructional methods.** *(emphasis added)*

It should be noted however, that all the research groups cited here have found that even with highly intensive and informed instruction, a number of children are resistant to the treatments given. This consistent finding points out the stability of severe deficits in phonological processing skills, as well as the need to examine the ways in which additional child characteristics (such as home and family background, demographic variables, and linguistic and dialectical characteristics) interact with specific treatment methods and approaches. What is clear from both the epidemiological and treatment studies is that early identification and early intervention are critical to helping children with reading disability gain

facility, in reading. As Shaywitz et al. [1994] have reported, **if youngsters with reading disability are not identified and provided with intervention before reaching nine years of age, at least 74% of them will remain disabled throughout their high school years.** *(emphasis added)*

FUTURE RESEARCH DIRECTIONS

We have addressed the role of definition in the conduct of science in the area of reading disability, and, in particular the role that poorly constructed definitions have played in our persistent inability to unravel the mysteries of reading disability. Perhaps the best example of the current state of science relating to reading disability can be found in the new definition of dyslexia proposed by the Orton Dyslexia Society discussed in detail by Lyon, [1995a]. The new definition is as follows:

> *Dyslexia is one of several distinct learning disabilities. It is a specific language-based disorder of constitutional origin characterized by difficulties in single word decoding, usually reflecting insufficient phonological processing. These difficulties in single word decoding are often unexpected in relation to age and other cognitive and academic abilities; they are not the result of generalized developmental disability or sensory impairment. Dyslexia is manifest by variable difficulty with different forms of language, often including, in addition to problems reading, a conspicuous problem with acquiring proficiency in writing and spelling.*

We cite this definition to underscore the scientific progress that has been made in our understanding of reading disability (dyslexia) during the past decade. In contrast to previous definitions, this one is inclusionary rather than exclusionary. It makes explicit, operational, data-based statements about the phenotypic expression of reading disability (deficits in single word decoding); the probable cause of such deficits (insufficient phonological processing); the genetic and biological underpinnings of the disorder (language-based disorder of constitutional origin); and its clinical presentation (unexpected in relation to age and other cognitive and academic abilities). In its last sentence, this definition also addresses the issue of co-morbidity, and is careful to limit exclusionary statements to only those conditions that have a distinctly different etiology (generalized developmental disability or sensory impairment). It is most important to note

that the definition has evolved directly from replicated research efforts. Certainly, the criteria specified in this definition are dynamic and subject to modification as new data become available. However, if science continues to prevail, any additions or modifications will be data-driven rather than policy-driven.

Future research efforts at the NICHD will continue to concentrate on the development of a valid and operational classification system for reading disability. In addition, emphasis is being placed on the development of instruments and intervention programs that will have the highest probability of success in identifying at risk children and applying efficacious treatment intervention programs. Substantial energy will be devoted to the application and interpretation of noninvasive structural and functional neuroimaging modalities to achieve better understanding of the linkages that exist among genotype, brain, and phenotype. The information derived from these research initiatives will be used to close the gap between observing and appropriately addressing the learning needs of children and adults with reading disability.