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A Multidisciplinary Journal

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Learning Disabilities Association of America

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Editor's Note

Learning Disabilities and Special Education under Attack

Special Education and the field of Learning Disabilities are under attack. Parents, professionals, and advocates of children with disabilities must be alerted to the bashing of special education in the press and the false charges about the failure of special education. They must respond quickly or we will loose all the gains we have made in the last twenty-five years, since 1975 and the passage of Public Law 94-142.

The Individuals with Disabilities Education Act (IDEA) is scheduled for reauthorization in the year 2002. Look at the Thomas E. Fordham Foundation Report, *Rethinking Special Education for a New Century* by C. Finn, A. Rotherham, and C. Hokanson at the website: http://www.edexcellence.net/library/special_ed/index.html While you are at this website take a careful look at Chapter 12, *Rethinking Learning Disabilities.*

To prepare the public for this reauthorization, some rather harsh articles about the value of IDEA and special education are appearing in the press. Bev Johns, President of the Learning Disabilities Association of Illinois, is a proactive advocate and active campaigner protecting the rights of children with disabilities and upholding the law. She argues that these articles are based on a combination of incorrect information and unrealistic expectations, and faulty research. Bev Johns notes the following false charges that:

- IDEA now provides financial incentives to identify children. In fact IDEA 1997 now provides financial incentives NOT to identify children.
- IDEA is subject to huge number of lawsuits. In fact an extremely small percent of students are involved in due process hearings, let alone lawsuits.
- Special education is a failure for almost all or the majority of its students. In fact, the lives of children who receive appropriate special education services are improved.
- Learning Disabilities does not exist. In fact, neurological research and MRI scans offer biological evidence of the existence of learning disabilities.
- Special Education does not produce as good a result as general education. In fact, there is widespread condemnation of general education.
- Simplistic solutions will solve all problems (full inclusion, co-teaching, stan dardized testing, *accountability*). In fact, these solutions will not make the child's disability disappear and often increase the problems for the child.

Special education has been an incredibly important program for millions of children. Graduation rates have increased, and the number of young adults with disabilities enrolling in college has more than tripled. Special education has helped people with disabilities become independent, wage-earning, tax-paying contributors to our country.

It is urgent that parents, educators, and advocates be alert to this political climate and attempts to eliminate special education and the rights of children with disabilities. We again need a proactive special education community.

The Articles in This Issue

The articles in this issue of ***Learning Disabilities: A Multidisciplinary Journal*** present important issues in the field of learning disabilities.

Statistical Analysis of the Eligibility Criteria and Procedures for Determining Learning Disabilities by S. Haight, L. Partriarca, and M. Burns examines the eligibility criteria and procedures that districts use to identify students with learning disabilities continues to be a controversial issue. This article reports an analysis of written documents from the Regional Services Agencies in the state of Michigan.

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Enhancing the Quality of Mathematics for Students with Learning Disabilities by J. Cawley and T. Foley focuses on mathematics and learning disabilities. The authors use subtraction to illustrate the importance of developing a quality they call *number sens*e. They point out that developing the concept of *Big Ideas* plays an important role in helping students with learning disabilities become problem solvers.

The Neurological Basis of Learning Disabilities: An Update by C. Fiedorowicz, E. Benezra, W. MacDonald, B. McElgunn, A Wilson & B. Kaplan was developed by a team of researchers at the Learning Disabilities Association of Canada in Ontario, Canada. The article brings together the recent neurological research findings in the field of learning disabilities and developmental dyslexia.

The Use of Tobacco, Alcohol, and Marijuana by Mexican American Adolescents with Learning Disabilities: A Longitudinal Study of Selected Risk Factors by D. Katims, Z. Vin, and J. Zaputa reports a longitudinal study designed to examine the causal effects of distal (at year one of the study) and proximal (at year three of study) of the risk factors for the use of *gateway* substances by Mexican American adolescents with learning disabilities.

Book Review: Research & Global Perspectives in Learning Disabilities: Essays in Honor of William M. Cruickshank by H. McGrady. This book, edited by D. Hallahan and B. Keogh, is a tribute to William M. Cruickshank. As a pioneer in the field of learning disabilities, Cruckshank has been an important contributor to the foundation and development of the field of learning disabilities. A number of well-known authors have contributed chapters to the book. Cruickshank was the founder of the organization known as the International Agency for Research in Learning Disabilities (IARLD), and many of the chapters in this book report on the international developments in the field of learning disabilities.

I want to thank Dr. Effie Kritikos, Northeastern Illinois University, for her help in reviewing manuscripts for this issue of the Journal.

Janet W. Lerner
Editor-in-Chief

A Statewide Analysis of the Eligibility Criteria and Procedures for Determining Learning Disabilities

Sherrel Lee Haight, Linda A. Patriarca, and Matthew K. Burns

To better understand the eligibility criteria and procedures districts use within one state to identify students with specific learning disability, written documents from the Regional Educational Service Agencies in Michigan were analyzed along four dimensions: (1) nature of document and type of written criteria, (2) prevalence and definition of severe discrepancy formula, (3) assessment measures, and (4) consistency. The data showed the majority of the districts had written criteria, and all of the districts with criteria included a severe discrepancy formula. Discrepancy scores varied widely in the documents, as did data on all of the other dimensions analyzed. Implications are discussed for the field and for further research.

The number of students identified as learning disabled has increased steadily since it became a federal category of special education in 1975 (Lerner, 2000). For example, in 1976-1977, the first school year Public Law 94-142 was implemented, 1.8% of the enrolled school population received services under the category of learning disabilities. Between 1976-1977 and 1992-1993, the number of students identified as learning disabled nationwide increased by 198%. By the 1996-1997 school year, the percent had increased from 1.8% to 5.5% (Lerner, 2000). Currently, students with learning disabilities represent the largest category of special education, comprising 51% of all students receiving special education services in the United States (Lerner, 2000).

Swanson (2000) refers to the increase in the number of students labeled as learning disabled as an epidemic. MacMillan, Gresham, Siperstein, and Bocian (1996) underscore this problem by stating that if these *epidemic-like figures were interpreted by the Center for Disease Control one might reasonably expect to find a quarantine imposed on the public schools of America* (p. 169).

Many argue that the definition of learning disabilities is to blame for this steep rise in the number of students identified with learning disabilities (Aaron, 1997; Fletcher & Foorman, 1994; Gresham, 1997; MacMillan & Speece, 1999; MacMillan, Grisham, & Bocian, 1998; Spear-Swerling & Sternberg, 1998; Swanson, 2000). Since the term learning disabilities was first introduced by Kirk in 1963 (Kirk, 1963), there has been continuous debate on the efficacy of the definition and its relationship to the identification of students classified as learning disabled (Fuchs & Fuchs, 1998; Fuchs, Fuchs, Mathes, Lipsey, & Eaton, 2000; Hallahan, Kauffman, & Lloyd, 1999; Kauffman, Hallahan, & Lloyd, 1998; Kavale, Forness, & MacMillan, 1998; McPhail & Palincsar, 1998; Siegel, 1989; Sleeter, 1998; Stanovich, 1986; 1991). According to Kavale (1995), learning disabilities has been defined as an *unexpected discrepancy* between intelligence and achievement, presumably caused by neurological impairment. Critics such as Hallahan, Kauffman, and Lloyd (1999) express concern that the definition is too broad and, consequently, leads to misdiagnosis. Gallimore (1999) agrees with these criticisms when he states that despite the valuable contributions of prominent researchers, the definition of learning disabilities continues to be ambiguous and the identification of learning disabilities unreliable.

An examination of national prevalence data revealed that 4.49% of school children are identified as learning disabled in this country. However, significant variance occurred between states with the lowest being 2.39% (Kentucky) and the highest being 7.35% (Massachusetts). Michigan's prevalence rate was 3.89% (US Department of Education, 2000). Therefore state departments of education and school districts alike continue to search for some objective and consistent means of identifying learning disabilities (California Department of Education, 1995).

The most prevalent tool discussed in the literature for improving diagnostic reliability is the discrepancy score, a mathematical calculation for quantifying the concept of severe discrepancy between achievement and potential (Gresham, 1997; Lerner, 2000). Nonetheless, there are many researchers and practitioners who question the validity of the IQ-achievement discrepancy procedures, arguing instead for other approaches (Aaron, 1997; Fuchs & Fuchs, 1997, 1998; Gresham, 1997; MacMillan & Speece, 1999). Still others advocate the use of clinical judgement and experience as the primary tools in deciding whether a given child is eligible for services under the learning disabilities category (Chalfant, 1989; Mastropieri, 1987). Although these debates continue to occupy a central place in any discussion of learning disabilities identification, most school districts, faced with the burden of identifying students, use some sort of formula as one criterion in determining eligibility (Frankenberger & Fronzaglio, 1991; Frankenberger & Harper, 1987; Mercer, Jordan, Allsop, & Mercer, 1996; Mercer, King-Sears, & Mercer, 1990).

Several different methods for determining severe discrepancy have been used in the schools and discussed by measurement specialists (Bennett & Clarizio, 1988; Cone & Wilson, 1981; Fletcher & Foorman, 1994; Forness, Sinclair, & Guthrie, 1983; MacMillan, Gresham, & Bocian, 1998; Reynolds, 1985; Richek, Caldwell, Jennings, & Lerner, 1996; Salvia & Ysseldyke, 2000; Willson, 1987). However, there is no agreement on which of these methods or formulas is the most accurate.

Research suggests that the nature of the discrepancy formula used does affect prevalence rates. Clarizio and Phillips (1989) revealed that using a regression procedure for determining severe discrepancy rather than a *z*-score method would result in fewer students being identified as learning disabled.

Discrepancy formulas have a prominent place in the identification of learning disabilities. Because criteria impact student eligibility, it seems important to identify the criteria that districts use to identify learning disabilities, and to examine how they operationalize the concept of *severe discrepancy*. Thus, this study was designed to address the following questions:

1. How many school districts in one state have written criteria for determining eligibility for learning dis abilities? What is the nature of these written crite ria and how consistent are they across the state?
2. Among those school districts that have written cri teria, how many have a formula as one criterion for determining eligibility? To what extent do these formulas vary across the state and in what ways?
3. To what extent do districts require or recommend the use of specific assessment measures to identify specific learning disabilities?
4. How comprehensive, explicit, and consistent are the written criteria for identifying learning disabil ities across the school districts surveyed in the state?

Methods

Procedures

The participants in this study consisted of Directors of Special Education and/or Coordinators of Special Education who worked at the Regional Educational Service Agencies (RESA) in the state of Michigan. RESAs are intermediate school districts which provide services such as, center programs, support personnel, professional development, and instructional materials to all of the public schools, charter schools, and private schools within their geographical region. There are 57 RESAs in the state of Michigan.

While the special education personnel were not the focus of this research, they served as the contact for acquiring the documents that were analyzed in this study. Directors of Special Education and/or Coordinators of Special Education in each of the 57 RESAs were contacted by telephone and asked whether they had any written eligibility criteria or set of procedures for identifying students with learning disabilities and, if so, they were asked to send a copy of their materials to the authors.

Of the 57 RESAs contacted, 12 (or 21%) had no written eligibility criteria or set of procedures for identifying learning disabilities. Of the remaining 45 districts that had written criteria and eligibility requirements, 30 (or 67%) responded to the initial telephone call by sending their written materials. A second follow-up phone call was made to the 15 districts that failed to respond to the initial requests and 10 more responses were received. Finally, a third follow-up phone call was made to the five districts that had not sent their materials and all responded. Thus, all of the RESAs (100%) replied to the request for eligibility criteria. The data analyzed in this study consisted of examining the written criteria and eligibility requirements of all the RESAs that had them in the State of Michigan.

After receiving the 45 documents, the researchers identified the specific variables to be investigated. Considering the nature of the database, the investigators identified 12 variables which they clustered under the following four categories. They were as follows:

Nature of Document and Type of Written Criteria. Under this heading the variables reviewed were: (a) the presence or absence of a written document, (b) the date document was published, (c) the number of pages of the written document, and (d) the types of criteria used to identify learning disabilities, such as severe discrepancy between potential and achievement or use of an exclusion clause.

Prevalence and Definition of Severe Discrepancy Formula. Here the researchers identified four variables: (a) presence or absence of a severe discrepancy formula in the written document, (b) the nature of severe discrepancy formula (e.g., standard score point differences, standard deviation differences between potential and achievement), (c) whether the district uses standard scores and statistical procedures such as standard error of measurement or regression toward the mean when calculating severe discrepancy.

Assessment Measures. In this category, researchers examined two variables: (a) the number of districts that *require* specific instruments be used in the assessment process, and (b) the number of district that recommend specific instruments be used in the assessment process.

Comprehensiveness, Explicitness and Consistency of the Criteria. In this category, researchers examined three variables: (a) *comprehensiveness* which refers to the number of distinct criteria that needed to be satisfied in order to qualify a child as having a specific disability, (b) *explicitness* which refers to whether these criteria were operationalized in the document, and (c) *consistency* which refers to the extent to which the stated criteria were consistent across

RESAs.

Using these variables, one researcher analyzed and coded each document. When all of the coding was complete, a graduate assistant independently coded the variables in each document. Any variable that did not have a one hundred percent agreement was re-coded independently by each person. There were no discrepancies in coding after the re-coding process.

Codes for each variable were entered into an Excel database. Tables were developed and descriptions written based on the coded data.

Results

Nature of Document and Type of Written Criteria

This descriptive study revealed that 21% (or 12) of the 57 RESAs in the state had no written eligibility criteria or set of procedures for identifying learning disabilities. Examination of the written documents from the remaining 45 RESAs indicated a lack of uniformity on several dimensions. One notable difference involved document length, which varied from 1 sentence to 112 pages. The modal length was 10-30 pages, which accounted for 35.6% of the documents. Another difference involved the types of information included in the documents. Some included reviews of the professional literature, philosophy statements, discussions of issues regarding specific criteria, teacher checklists, statistical reference tables, suggested assessment instruments, data-recording forms, observation forms and recommended classroom accommodations, while others did not. Although every document did not specify a publication date, the majority did and those dates ranged from 1983-1998. The mode was 1987 and the median was 1990.

Explicitness of the criteria used to identify learning disabilities varied widely across RESAs. Data excerpted from the documents were categorized according to five different levels of specificity: (1) Severe Discrepancy Score Only, (2) Severe Discrepancy Score and Documentation of Need for Special Education (SE) Services, (3) Severe Discrepancy Score, Documentation of Need for SE Services and Exclusion Criteria, (4) Severe Discrepancy Score, Documentation of Need for SE Services, Exclusion Clause and Central Process Dysfunction, and (5) All required in #4 except that the processes for determining Central Process

Table 1

Criteria Used by Regional Educational Service Areas for Determining Learning Disabilities Eligibility (1997-98)

Types of Eligibility Criteria	Components of the Criteria	No. of Districts	%
Formula Only	Must document a severe discrepancy between Intelligence and Achievement in 1 of 7 areas. Discrepancy was quantified.	2	4.4
Formula, General Education (GE) alternatives with need for special education services	Same as above PLUS: Must document the need for Special Education (SE) services by trying problem-solving alternatives in General Education (GE).	1	2.2
Formula, GE alternatives, Exclusion	Same as above PLUS: Must document the exclusion of the other disabilities as the primary cause and other explanations for the discrepancy (e.g., cultural, educational opportunities, illness).	17	37.8
Formula, GE alternatives, Exclusion, Central Process Disorder (CPD)	Same as above PLUS: Must document some evidcence that a Central Process Disorder exists but the nature of that evidence is unspecified. Same as above EXCEPT that the nature of the evidence for documenting a CPD is specified in one of three ways:	15	33.3
	Central Process disorder is defined by scores on specific assessment instruments and the relationship of those scores to achievement areas.	2	4.4
	Central Process Disorder is defined by intrascale score variability by cluster analysis on a formal assessment	3	6.7
	Central Process Disorder is defined by methods specified in either of the above	5	11.1

Note: 12/57 (or 21%) of the RESAs have no written criteria.

Dysfunction are specified. In Table 1, we identify and describe these five different levels.

As the table shows, RESAs did designate criteria for determining eligibility but those criteria ranged from a simple documentation of discrepancy to a set of criteria that included documenting intrascale variability as a procedure for determining the existence of a Central Process Disorder. As expected, most of the districts' criteria (70%) could be said to cluster in a mid-range of specificity. That is, the districts identified the constructs they wanted documented, but did not specify how this should be done or designate explicit, quantifiable criteria for doing so. In fact, only 8 districts (18%) actually specified using particular instruments or identified quantitative procedures for documenting the presence or absence of a Central Process Disorder.

Prevalence and Definition of Severe Discrepancy Formula

Looking specifically at the presence or absence of a severe discrepancy formula, all school districts with written eligibility criteria used some type of formula to determine severe discrepancy. As for the nature of the severe discrepancy formula, all of the formulas were based on some form of standard score point difference between the intelligence quotient score and the achievement score in one or more of the seven achievement areas. Of interest here are the variations that were found within this theme. Some districts (50%) used a single score to denote discrepancy, such as 15 points, while other districts (20%) used two different scores to calculate discrepancy, based on whether the achievement scores were being compared to the verbal or performance scale scores on the intelligence measure. Finally, there were a few districts (27%) that calculated the degree of correlation between the specific intelligence and achievement tests used and, then, based on this figure, identified a standard score discrepancy criterion. Table 2 provides more detail on these variations. As shown in Table 2, there were 11 total severe discrepancy formulas used in Michigan. Furthermore, in the 45 districts only 24 of the districts' criteria included student assistance teams, and only 7 included curriculum-based assessment (CBA).

In reviewing this table, one should note that, even though over 50% of the districts used a single standard score point difference formula to calculate discrepancy, the differences in standard score points required ranged from 1 standard deviation (15 points) to 2 standard deviations (30 points). Another interesting finding worthy of note is that roughly one-third of the districts surveyed used the least complex method of calculating discrepancy. When calculating severe discrepancy, 30 of the 45 school districts (or 66%) used standard scores and statistical procedures such as standard error of measurement and/or regression toward the mean.

Assessment Measures

Only 1 of the 45 school districts (or 2%) *required* that specific assessment instruments be used while another 22 of the districts (or 48.8%) *recommended* specific assessment instruments. Typically, the recommended instruments were presented as lists of specific standardized test instruments under each area of assessment in the definition of learning disabilities, such as Listening Comprehension or Written

Table 2

Summary of Information on RESA Criteria and Procedures for Determining Learning Disabilities Eligibility

Severe Discrepancy Formula Score	No. of Districts	% of Districts	Year(s) Printed	No. of Districts Using SAT	No. of Districts Using CBA
15 Standard Score Points	4	8.9	1982 (2), 1991, 1994	2	0
18 Standard Score Points	8	17.8	1987, 1988, 1989, 1990, 1994,1998, no date (2)	7	0
20 Standard Score Points	9	20.0	1985, 1989, 1990, 1991, 1995, 1997, no date (3)	4	2
18-21 Standard Score Points	2	4.4	1986, no date	0	0
18 for VIQ; 20 or 21 for PIQ	5	11.1	1990, 1991, no date (3)	3	2
18-24 for PIQ	1	2.2	1983	0	0
.01 significant level	1	2.2	1995	0	0
16 (.7), 18 (.6), 20 (.5)	9	20.0	1987, 1988, 1991, 1992 (2), 1995, no date (3)	4	2
22 (.7), 24 (.6), 26 (.5)	3	6.8	1991, 1996, 1997	2	1
1-1/2 Standard Deviations	1	2.2	1987	1	0
2 Standard Deviations	2	4.4	1987, no date	1	0

Note. SAT=Student Assistance Teams; CBA=Curriculum-based Assesment; VIQ=Verbal IQ; PIQ=Perforamnce IQ.

Expression. Fifty of the RESAs provided no guidance to professionals regarding the processes, measures or tools to use in assessing potential or achievement.

Comprehensiveness, Explicitness and Consistency of the Criteria

The number of district criteria that needed to be satisfied for a student to qualify as having a specific learning disability ranged from one (formula only) to eight different criteria, including evidence of a Central Process Disorder determined by one of several specific statistical procedures. Table 3 provides details of the re-evaluation criteria used by each district stipulating separate criteria from eligibility decisions and the number of districts that used each one. Variations among these criteria are as evident in the re-evaluation criteria as in eligibility criteria.

While all of the school districts with written eligibility procedures used a severe discrepancy formula, most districts (43 of 45 or 96%) used more criteria than just the severe discrepancy formula to determine eligibility. However, here again wide variation exists. For example, looking at the concept of Central Process Disorder, it becomes apparent that 44% of the RESAs (or 20 districts)) did not mention Central Process Disorder as a criterion for eligibility in the category of specific learning disability. Thirty-three percent of the districts (or another 15) mentioned the need to document a Central Process Disorder as a criterion in identifying learning disabilities but did not operationalize it. Another 22% (or 10 districts) not only discussed the need to document a Central Process Disorder but also provided specific procedures for obtaining the evidence. These data highlight the diversity of approaches districts use in dealing with the concept of causation in the definition of learning disabilities. Districts differed not only in the number of criteria they used but also in the extent to which they operationalized these criteria.

Table 3

Number of RESAs Using Each Type of Severe Discrepancy Criterion for Three Year Re-evaluation of Specific Learning Disability

Three Year Re-evaluation Criteria	No. of Districts
A score of 10 Standard score points	1
A score of 15 Standard score points	9
A score of 17 Standard score points	1
A score of 20 Standard score points	3
A score of 15 for Verbal IQ or 18 for Performance IQ	1
A score based on the strength of the correlation between the test of Potential (intelligence) and the test(s) of Achievement (.5, .6, or .7 Correlation)	3
Curriculum-based Assesment	1
A Continuation Rational	5

Discussion

In the state of Michigan, 79% percent of the RESAs had written criteria for determining learning disabilities, and of those school districts, 100% used a severe discrepancy formula as one of those criteria. Although all were based on the difference between the student's intelligence test scores and achievement scores, the discrepancy formulas had some variance within them. The size of the discrepancy needed ranged from 1 standard deviation (15 points) to 2 standard deviations (30 points) across RESAs. Others required that professionally accepted statistical procedures, such as accounting for standard error of measurement or using a regression formula, be used when making eligibility determinations. However, because most districts used some statistical procedure, such as a regression formula, to achieve the point total necessary for a severe discrepancy, it appears that the only significant difference between the districts' models was the size of the point total deemed large enough to represent a severe discrepancy.

Reschly (1995) pointed out that variance exists between states in how IDEA categories are adopted, and suggested that children with identical characteristics could be diagnosed with a disability in one state, but not in another. The data from the current study suggest a similar scenario exists between RESAs within a state. Therefore, it is theoretically possible for a child to be diagnosed with learning disabilities in one district, but to lose that diagnosis with a move to the neighboring district. Although these data are limited to one state, it is reasonable to assume that similar situations exist in other states as well, given the vague nature of most learning disabilities definitions.

A lack of consistency between districts extends beyond the discrepancy formula, in that only 51% of those with written criteria recommended specific assessment instruments. Several researchers have demonstrated that the achievement test selected can impact the score and, thus, eligibility. Additionally, Wilson and Reschly's (1996) survey of practicing school psychologists suggested that many do not select the most technically adequate assessment tools. Only one district (2%) mentioned curriculum-based assessments in their criteria, but the literature contains frequent calls for increases in the use of CBA data to assess learning difficulties (Burns, MacQuarrie, & Campbell, 1999; Elliot & Fuchs, 1997, Fuchs & Fuchs, 1996, Kaminski & Good, 1998; Rosenfield & Gravios, 1996; Shapiro, 2000; Tucker, 1987).

Within the larger context of the special education eligibility assessment process, Fuchs and Fuchs (1996, 1997) have proposed using curriculum-based measurement to identify students with disabilities, as well as assess treatment validity and student growth. Shapiro and Eckert (1994) surveyed practicing school psychologists and found that CBA was significantly and consistently rated as more acceptable than traditional achievement tests, but the use of this assess-than traditional achievement tests, but the use of this assessment approach among school psychologists remains limited (Shapiro & Eckert, 1993). Perhaps CBA not being mentioned in the district guidelines suggests a lack of administrative support for this tool and may be a potential barrier to its implementation. However, these are hypotheses that would need to be studied further.

Perhaps the most significant finding of the current study is not what is currently implemented, but what is not. There are extensive criticisms of the discrepancy model within the research literature (Aaron, 1997; Fletcher, et al., 1998; Meyer, 2000). Gresham (1997) has responded to these criticisms by summarizing several recommendations from the literature.

1. One recommendation is to eliminate the concept of the ability/achievement discrepancy and use a spe cific level of academic achievement, such as the 25th percentile or the 10th percentile.
2. Another recommendation is to use a concept of dis crepancy between achievement areas or cognitive areas, such as an achievement-achievement dis crepancy scores (mathematics calculation, basic reading skills, listening comprehension, or reading comprehension).
3. A third approach is referred to as the resistance to treatment or intervention notion. This approach involves measuring a student's responsiveness to treatment over time. With this approach, the stu dent who is most resistant to treatment is the one who makes least progress and, therefore, most like ly needs special education services.

However, there was no mention of any aspects of proposed alternative definitions in the criteria collected for this study. This suggests there may be a large gap between research and practice, at least according to RESA documents in the State of Michigan.

It is interesting to note that many districts made no mention of pre-referral intervention as a documented step in the process of assessing learning disabilities. Only 26 of the 45 RESAs discussed student support or teacher assistance teams, which suggests that less than half of the 57 RESAs currently document using this recommended step (Burns, 1999; Sindelar, Griffin, Smith, & Watanabe, 1992) and federally mandated component of a learning disabilities assessment.

Future researchers may wish to examine the extent to which these variations in discrepancy formulas actually matter in the process of identifying students with learning disabilities. Further qualitative research into the multidisciplinary evaluation team decision-making process may also provide more penetrating insights into the criteria actually used when arriving at eligibility decisions. Designing paper cases and interviewing diagnostic teams or focus groups about the information they would use and the decisions they would make to determine eligibility may be one approach. Another method may be to observe the diagnostic teams as they engage in the process of differential diagnosis with an actual student referred for services. Finally, a replication of the current study with a national sample may be of interest.

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Enhancing the Quality of Mathematics for Students with Learning Disabilities: Illustrations from Subtraction

John F. Cawley and Teresa E. Foley

The general purpose of this paper is to offer a response to the question raised by Dr. John Lloyd, With all that we know about special education and teaching, why don't we do better than we do? and to the concerns of Russell Gersten and David Chard with respect to number sense. This paper suggests that the reason the mathematics performance of students with mild disabilities is so limited is the mathematics. Using a set of illustrations from subtraction, the authors propose (1) that number sense be a primary goal and that within the realm of number sense, big ideas be included among the dependent variables. Problem solving that assists students to become problem solvers rather than students who follow routines to obtain answers to problems should be a priority. It is suggested that assessment move away from a system that seeks only correct responses and move toward a system that seeks information concerning student ability to communicate mathematics principles, reason, prove and explain mathematics, and demonstrate connections between mathematics and other subjects.

In writing the President's Message for *Focus on Research*, Lloyd (1997) commented, *With all that we know about special education and teaching, why don't we do better than we do?* (p. 1). Gersten and Chard (1999) proposed that some special education students who are *drilled on number facts and then taught various algorithms may never develop number sense*. We believe that the lack of attention to number sense as expressed by Gersten and Chard is the root of the problem cited by Lloyd. That is, the programs provided to students with learning disabilities stress the rote learning of number facts and routines, but fail to enhance the quality of the mathematics presented to the students.

Our general sense is that the concerns of Lloyd and Gersten and Chard are related to the following:

- Students with learning disabilities do poorly in mathematics because the field has failed to address the mathematics.
- Special education has yet to explore alternative conceptualizations of mathematics and to include within these conceptualizations the importance of both *knowing* and *doing* mathematics.

The purpose of this paper is to describe a perspective on mathematics that focuses on the quality of the mathematics presented to students and strives to raise their levels of *knowing* and *doing* mathematics within a single topic, subtraction. Subtraction is a vital subject and as noted in a study of teacher-identified mathematics behaviors, *renaming* in subtraction is among the more important indices of student deficits (Bryant, Bryant, & Hammill, 2000). Comparable considerations apply to other aspects of mathematics. The current paper does not address instructional concerns per se, although it is recognized that teachers and research specialists may prefer to use a variety of instructional procedures to address different mathematics. The focus of the paper is on an alternative framework of mathematics to be presented to students with learning disabilities.

Subtraction was selected for three reasons. First, it is a topic that is taught early in the primary grades and students have significant experience with it throughout their elementary years. Second, it is a topic that is far more meaningful than the rote computation *take away* approach that is frequently taught. The *take away* view of subtraction has been advocated for students with mild disabilities since the 1920s when Inskeep (1926) indicated that subtraction should be taught as a process of *take away*. However, long before Inskeep, and earlier Burnham (1849) defined subtraction as a process to use in finding the *difference* between two numbers. Third, consistent with importance of the notion that mathematics for students with learning disabilities should stress *big ideas* (Carnine, Jones, & Dixon, 1994), we suggest that the big idea in knowing about subtraction is that it represents *difference*. How else would a student explain and justify subtraction in word problems such as

- Nakisha has 7 apples. This is 3 more than Jamol. How many apples does Jamol have?
- Angelica added 6 apples to her pile. She now has 7 apples. How many apples did Angelica have when she started?
- Shanna has 3 apples. Ryan has 7 apples. How many apples does Shanna need to add to have as many apples as Ryan?

This paper makes a distinction between *knowing about* subtraction and being able to *do* subtraction. *Knowing about* subtraction involves reasoning in the form of proof and explanation, an ability to communicate mathematics meanings through symbolic and manipulative representations and demonstrate the connectedness between one facet of mathematics (e.g., subtraction) and another (e.g., addition) or between mathematics and other subjects. We suggest five considerations that represent *knowing about* subtraction. They are:

1. Subtraction is *difference*. Subtraction is not *take*

away. The difference principle is evident when students analyze and discuss situations of the following types.

- Determinations of what number must be added to another to make them the same.
- How much larger/smaller is one number than another.
- What remains of a number after part of it has been taken away.

2. The reason there is a difference between two numbers is that the sets of numbers lack *one-to-one* correspondence. When the numbers in each set are the same, there is *one-to-one* correspondence, thus no difference and the answer is 0.

3. Subtraction takes place in only one column, whether the column be 1s, 10s, 100s and so forth and that the largest number involving renaming is 18 (i.e., 18 - 9; 180 - 90 require renaming). Thus, understanding place value is fundamental to subtraction involving two or more digits.

4. There are many approaches to subtraction. Students can learn the traditional decomposition method; they can learn borrow-payback, the complementary method and the additive method (Hatfield, Edwards, Bitter & Morrow, 2000; Reisman, 1977). They can also learn multiple ways of completing items such as going from right-to-left or from left-to-right. They can also integrate and compare various item formats such as manipulative representations, expanded notation and the traditional numeration format.

5. Addition and subtraction are inverse operations. When teaching about subtraction, addition should be taught simultaneously. Students should know that addition can be proved by subtraction (e.g., 6 + 2 + 5 = 13 as 13 - 5 = _ - 2 = _ - 6 = 0) and subtraction can be proved by addition (e.g., 13 - 6 = 7 as 6 + _ = 13). Students' understanding is evident when they can explain and demonstrate that when a subset is removed from a set and then returned to the set, the restoration returns the set to its original composition (Sheffield & Cruickshank, 2000).

To consider the first principle as a dependent variable, assume that a teacher presented students with the following items 8 - 3 = _; 9 - 4 = _; 6 - 1 = _ and asked students to complete the problems and explain why the answer is the same for each item. Students should reply with something like, *It's because the difference (i.e., 5) between the two numbers is the same*.

Assume further that the teacher presented students with the following 8 - 8 = _; 7 - 7 = _; 3 - 3 = _ and asked them to complete the problems and explain why the answer for each item is 0. Students would be expected to indicate that (1) the number of items in each set is the same, so there is no difference or (2) the number of items in each set are in one-to-one correspondence so they are the same.

Doing subtraction could include the following 5 basic principles.

1. Activation of the processes by which the difference between numbers is determined. For single digit subtraction this involves finding the difference between a larger number (e.g., 8) and a smaller number (e.g., 5). This is an important principle of subtraction because it reduces the chances that a *bug* will occur (Baroody, 1991). Experience with missing addends is important as students complete activities such as _ + 5 = 8 where the greater number is the *bottom* number.

2. Students' use of *facts* should be fluid and accurate (NCTM, 2000).

3. When subtraction involves two or more digits, students should be able to use multiple algorithms. Doing a single item with three different algorithms represents a higher quality of mathematics than doing three different items with the same algorithm (Cawley & Parmar, 1992).

4. Students should be able to represent subtraction of two or more digits using expanded notation to explain the transition from manipulative to traditional symbolic representations.

5. Subtraction, unlike addition, is not commutative. Thus, changing the order of the numbers *will* change the answer.

Within the realm of existing intervention research in subtraction and students with learning disabilities, the dominant focus is on *instructional practices* and the dominant dependent variable is percent correct or number correct on paper-pencil tasks. Our search of literature identified only one study that actually examined an alternative mathematics. That study, an examination of the *equal additions*, (Sugai & Smith, 1986) indicated that students with learning disabilities showed an increase in percent correct and some generalization to novel problems when the algorithm was presented using a demonstration modeling technique.

Related Literature

Let us begin this brief summary of literature with the work of Linda Cox (1975) who studied systematic error patterns for the vertical operations of computation on whole numbers among students with and without learning disabilities. Specific to subtraction, Cox differentiated error patterns as (1) *systematic*, or those in which students repeatedly made the same error in the algorithm, (2) *random*, where students made numerous errors, but no error pattern was observed, and (3) *careless*, when students made one or two errors, but basically knew how to work the algorithm. For subtraction, the systematic error pattern included 28 different error patterns for renaming, 16 systematic errors for concept of subtraction, 6 for wrong operation and 2 for place value. The data show that 14% of the sample made identical systematic errors one year later and that 9% were making a different systematic error one year later.

Blankenship (1978) conducted one of the earlier intervention efforts. She utilized a demonstration plus feedback approach to remediate systematic inversion errors in the subtraction performance of 9 students with learning disabilities. Performance was assessed in 6 sessions and instruction was provided in 6 sessions. Errors reduced from 88% to 6%. Eight of the students generalized to other problems and most retained their performance levels one month later.

Frank, Logan and Martin (1982) also investigated error types for subtraction in 94 students with learning disabilities. They found both systematic and random errors with an increase in systematic errors as students moved from items without *zeros* to those that contained zeros.

Over the years, a number of instructionally rooted intervention efforts have been conducted with subtraction. These include:

- Goal Setting and Self-Efficacy (Schunk, 1985)
- The effects of strategy training and feedback through verbalization (Schunk & Cox, 1986).
- The use of applied behavior analysis (Rivera & Smith, 1987)
- Self-monitoring (Dunlap & Dunlap, 1989)
- Application of concrete-to-abstract sequencing (Miller & Mercer, 1993: Scott, 1993; Sutherland, 1993)

A general finding within the literature is that students in a variety of treatments tend to improve. An additional observation is that the dependent variables focus on increasing correct responses or decreasing errors in symbolic computation activities such as paper-pencil computation. In effect, the *big idea* (Carnine, et al., 1994) is seldom addressed.

Background Data

Table 1 displays a set of subtraction data (Cawley, Parmar, Miller & Yan, 1998). It is included here for the convenience of the reader and to support the need for reconsideration of existing approaches to subtraction. The criterion level for student mastery was established as two consecutive ages with 70% correct or higher. Normally achieving students (SNA) attained mastery for single digit and two digit combinations at ages 9 and 10 respectively and through four digit combinations at age 12. Students with learning disabilities (SWD) did not meet criterion on single digit items until age 13 and some 30% or more did not meet criterion on four digit items through age 14.

Process Considerations

With the goal that students will become *problem solvers* rather than students who use explicit routines to derive answers, it is important to consider problem solving as an overall heuristic rather than a specific process. Accordingly, problem solving is an integral component of number sense as it can be built in and analyzed in a variety of tasks. For example, we can view a pair of items such as 5 - 2 = 3 and 8 - 5 = 3 from a *problem solving* perspective by asking students to explain how two different number combinations result in the same answer (i.e., *You get the same answer because the answer represents the difference between the numbers in each combination.*). This could be extended with items such as 5 + 3 = 8 and 8 + 3 = 11 where adding the same number (i.e., 3) results in two different answers and students are asked to explain why. Math can be viewed from a *communications* perspective by asking students to provide alternative representations or to use alternative algorithms to demonstrate meaning. *Connectedness* could be shown by asking students to indicate how subtraction and addition go together or how subtraction could be used to solve real-life or contrived problems or to use combinations to actually create problems applicable for different subjects. *Reasoning*

Table 1

Developmental Subtraction

Grade	**3**		**4**		**5**		**6**		**7**		**8**	
	SNA	**SWD**	**SNA**	**SWD**	**SNA**	**SWD**	**SNA**	**SWD**	**SNA**	**SWD**	**SNA**	**SWD**
Set 1												
(8)												
N	123	26	132	35	130	38	114	39	129	39	109	20
Mean	4.7	3.1	5.4	4.4	6.8	5.2	6.3	5.1	7.4	6.1	7.2	4.4
SD	3.3	2.9	3.3	3.3	2.5	3.0	3.1	3.6	1.8	2.8	2.2	3.5
Set 2												
(8)												
N	48	-	71	11	89	15	83	18	120	24	99	-
Mean	6.9	-	6.9	6.4	7.6	7.5	7.7	7.3	7.8	7.0	7.2	-
SD	1.7	-	2.2	2.4	1.1	1.6	0.9	1.5	0.7	2.2	1.0	-

First and Last Item in Set 1: 16 - 3; 50 - 24

First and Last Item in Set 2: 460 - 48; 8000 - 6341 could be invoked by asking students to justify their answers and explain the process they use to arrive at their conclusions. For example, students might be asked to explain and justify why the following are subtraction problems:

- Rosa has 8 apples. This is 3 more than Anthony has. How many apples must be added to Anthony's apples to give him as many as Rosa? or
- Nakim added 8 apples to his pail. There are now 11 apples in the pail. How many apples were in the pail before the 8 apples were added?

Representations involve both physical and mental images. For example, assume students are presented with three problems as follow:

- Take away 3 objects from a set of 5.
- Determine how much taller a tower of 5 blocks is than a tower of 3 blocks.
- Determine the number of blocks needed if a tower has 3 blocks, but needs a total of 5.

A common representation for the three problems is the number sentence 5 - 3 = 2 (NCTM, 1998). Representing the same problem in different ways accentuates comprehension by examining different features of the situation; using the same representation for different situations highlights the commonality in their underlying mathematics.

Efficiency is fundamental to automatization and speed and is examined with time/accuracy ratios and by observational data involving student actions and products.

Important Mathematics: Big Ideas

Two considerations stand out when examining mathematics from a qualitative perspective. First, there is no single way to do or to know mathematics. Second, there is no single way to organize mathematics for instructional purposes. For example, the customary sequence for computation is addition, subtraction, multiplication, and then division. This is not necessary. Division could be introduced first (Cawley & Parmar, 1992).

Numerous gaps exist in the data needed to select one approach over another. For example, there is uncertainty about whether the operations of addition and subtraction should be taught simultaneously as *relations* and *reversible operations* or whether they should be taught separately, as facts. Sheffield and Cruickshank (2000) state: *We want children to see that subtraction is the inverse of addition. To achieve this, we need to teach subtraction at the same time we teach addition. Children must be able to see the relationship between a collection of objects and a subset of that collection in order to understand subtraction. When a subset is removed, the idea of subtraction is understood if children realize that returning the subset to the collection restores the collection to its original state.*

There is uncertainty about whether students should be taught all the combinations of single digit subtraction (i.e., *the facts*) or whether they should be taught only 4 or 5 facts and then be held responsible for generating and mastering the remainder (Putnam, DeBettencourt, & Leinhardt, 1990). These researchers examined the performance of students with learning disabilities and general education students on their explanations of derived facts for addition and subtraction. About 50% of the students gave acceptable explanations for addition and 10-20% for subtraction. Students with learning disabilities, although lagging behind general education students, gave explanations that were comparable to those of other students.

Within the realm of work with numbers, Gersten and Chard (1999) suggest that a top priority be given to the development of *number sense*, which can be described as fluidity and flexibility with numbers, knowing what numbers mean, an ability to perform mental mathematics, representing the same number in multiple ways and inventing personal procedures for conducting numerical operations. Number sense also involves being able to respond to a variety of different assessments and to explain, justify and prove one's work.

Number sense is what a student knows and thinks about numbers, how they are organized and manipulated, and how they interrelate with one another (e.g., the interrelationships among 6 + 2 = _; 6 + _ = 8; _ + 2 = 8; 8 - 2= _; 8 - 6 = _; 8 - _ = 6; _ - 6 = 2; _ - 2 = 6). Or successive subtraction as investigated by Roy (2000) with items such as 24 - __ = __ - __ = 15, where students determine the missing addends.

Single Digit Subtraction

Figure 1 describes six activities with simple subtraction. The activities encourage students to construct and use number sense, to reason, to become active rather than passive learners and to share the values of a sociocultural environment for learning (Roy, 2000).

The items in row 1 determine the speed and accuracy to which students respond to computation of simple items. Row 2 changes the role of students from responder to producer and row 3 asks students to reason, explain, and prove. Row 4 provides an opportunity for students and teachers to compare a number of combinations that lead to a single answer. Row 5 requests students to construct an item that results in the given answer and row 6 asks students to conduct multi-step subtraction. The sample items provide numerous opportunities to (1) examine diversity in thinking and reasoning, (2) encourage discourse among students and (3) examine the interactive nature of learning as students contrast and justify their work with other members of the group. The six lessons were extensively studied in one classroom with a group of 15 intermediate students with learning disabilities (Roy, 2000). Each lesson was first videotaped, the videotape was then copied to audio tapes and

Figure 1

Six Subraction Activities

1. Write the correct response for each of the following items:

6	5	4	7	3	5
-3	-3	-2	-1	-2	-2

2. See the two sample items: In the time allowed, write as many items with similar characteristics as you can. Give the answer.

7	6
-2	-3

3. Write the correct response for each of the following items:

6	11	29	34
-4	-9	-27	-32

* Explain how these number combinations that are so different can all have the same answer.

4. Write the correct answer for each of the following items:

8	8	8	2/8
+2	-2	x2	

* Explain how these number combinations that are all the same, each can have a differnet answer.

5. Each of the items below has an answer. Write number combinations that make that answer.

- __	- __	- __	- __
7	9	6	13

6. Do 2 take *aways* to make 29 into 11.
29 - 12 = 17 - 6 = 11
29 - 8 = 21 - 10 = 11
29 - __ = __ - __ = 11

Do 3 take *aways* to make 29 into 11.
29 - 5 = 24 - 11 = 13 - 2 = 11
29 - 14 = 15 - 3 = 12 - 1 = 11
29 - __ = __ - __ = __ - __ = 11

the audio tapes were transcribed to print format. Students' worksheets and other data were also collected and an extensive qualitative analysis of the activities was undertaken. When students constructed items, their accuracy rate was between 90 and 100%. The activity in row 5 that called for the creation of number combinations that would provide a specified answer resulted in the extensive use of number patterns by students (e.g., 7 - 1 = 6; 8 - 2 = 6; 9 - 3 = 6 etc). An interesting feature of activity 6 was that students recognized the primary difference in 29 - _ = _ - _ = 11 as 29 - 18 and many proceeded to subdivide the 18 in many different ways. One student used the same subset of numbers as 29 - 9 = 20 - 9 = 11, 29 - 8 = 21 - 1 = 20 - 9 = 11, 29 - 1 = 28 - 8 = 20 - 9 = 11 where the 20 - 9 was a constant.

The following anecdote from one tape is illustrative of the activity in the classroom.

Students were asked to make their own set of items. The teacher asked various students to go to the board, put their items on the board and then discuss them. One student put two items on the board. They were 44 - 23 = __ and 44,000 - 23,000 = _____. The teacher asked the student if one item (i.e., 44,000 - 23,000) was harder than the other. The student responded, "No it is not any harder. It is just longer because you can forget the zeros."

This expression of number sense is common throughout the lessons and prominent when the lesson encouraged students to use their own thinking and item development.

Gersten and Chard (1999) address the relationship between decoding for reading and decoding for mathematics at beginning levels. Decoding for mathematics has long concerned us and over a period of many years, we have used a technique called Yap and Yan to explore this phenomenon. The *Yap and Yan* technique allows teachers to explore the extent to which students decode the relationship between symbols and their meanings as indicted by their ability to complete number sentences presented in meaningful, but unfamiliar text (see Figure 2).

Yap and Yan were designed as tasks to determine students' understanding of relationships involved in addition and subtraction (*Yap*) and multiplication and division (*Yan*).

Figure 2

***Yap*: A Bit of Number Sense**

Part A YAP = ::

HIF + HIF + YAP	___+___=___
ZIM - HIF = YAP	___-___=___
ZIM + HIF = CIM	___+___=___
HIF - HIF = TIB	___-___=___
TIS + TIS = ZIM	___+___=___
ZIM + TIS = ARB	___+___=___
ARB - HIF = DOF	___-___=___
DOF - HIF = WUM	___-___=___
WUM - YAP = LEB	___-___=___
DOF + TIS = BAZ	___+___=___

0 = ___	1 = ___	2 = ___	3 = ___
4 = ___	5 = ___	6 = ___	7 = ___
8 = ___	9 = ___	10 = ___	

Figure 2 continued

Part B

TIB	LEB	HIF	TIS	YAP	WUM	ZIM	DOF	CIM	ARB	BAZ
0	1	2	3	4	5	6	7	8	9	10

LEB	TIS	ZIM	TIB	ARB	BAZ	HIF

TIS	ARB	BAZ

BAZ	HIF	YAP	WUM	LEB	DOF	DOF	HIF	CIM	ZIM	CIM	YAP

WUM	TIS	DOF	ZIM	CIM	WUM	CIM	LEB	LEB	TIB

TIB

CIM	HIF	DOF	ZIM

TIS	TIS	YAP	HIF	ARB	ARB

TIB	DOF	LEB	BAZ	BAZ

HIF	WUM	WUM	ZIM	ARB	BAZ	CIM	LEB	YAP	YAP	TIB	TIB

ARB	WUM	TIS	HIF	ZIM	ZIM

Only *Yap* is illustrated here.

Yap is a three part task in which students decode non-word symbol combinations, derive meaning for the symbols and then insert the corresponding numeral sentence. Students cognitively examine the items to determine their underlying relationships, which then gives the numeral combinations. For example, given *Yap* as 4 (::) and the code HIF + HIF = __ students must determine that the two numerals have to be the same and when added together yield 4.

Once students have completed the decoding (Part A), a second stage is presented in which students practice the symbol/numeral relationships (Part B). Upon completion of this component, students are presented with a computation test in the non-word symbolic form (Part C). Overall, data indicate that students without disabilities perform well on both *Yap* and *Yan*, where as students with learning disabilities experienced difficulty with *Yan*, the multiplication and division component. What *Yap* demonstrates is that students with learning disabilities can interpret and apply principles, learn an alternative code and use the code in a relatively

Figure 2 continued

Part C

Example:	LEB
	+ HIF
	TIS

ZIM +HIF	YAP +TIS	ZIM +LEB
DOF HIF +LEB WUM	YAP WUM +WUM TIS	TIS TIS +LEB HIF
DOF -TIS	ARB -HIF	CIM -DOF
ARB DOF -YAP ZIM	WUM ZIM -HIF HIF	HIF WUM -LEB TIS

short period of time. What remains perplexing is why students do so reasonably well in this activity, yet do so poorly in the rote numeral-only format.

Multi-Digit Subtraction

Assuming activities with single-digit items have informed students of the basic meaning of subtraction as the *difference* between numbers, and students recognize that subtraction takes place under multiple conditions (e.g., What must be added to a number to make it as large as another number?), there are a number of issues that need to be addressed in order to proceed to multi-digit subtraction. Two considerations enter into the decision-making process. First is to what extent do students meaningfully understand place value and expanded notation. For example, the revised standards (NCTM, 1998) indicate students must not only recognize 87 as 8 10s and 7 1s, but also recognize 87 when it is represented as 7 10s and 17 1s or 98 - 11 and so forth. Second is the extent to which students and teachers acknowledge there is more than one way to know and do computation. While a preference of the authors is to introduce multi-digit subtraction with a left-to-right algorithm, others may not agree. Support for the left-to-right algorithm is found in the work of Kamii and her colleagues (Kamii, Lewis, & Livingston, 1993) who demonstrated how young children who developed their own procedures used the left-to-right algorithm. The work of Lee (1991) explains how *estimation* is basically a left-to-right function and provides additional support for this alternative algorithm.

Table 2 shows the subtraction performance of students in a general education fourth-grade classroom. The classroom included 3 students *at risk* in math, 4 students with learning disabilities and 16 normally achieving students. Consistent with the intent of the 1997 amendments to IDEA, all students were being educated in the general education classroom via the general education curriculum.

One of the authors visited the classroom, wrote a set of subtraction items on the chalkboard and asked the students to do them the way they were taught by their teacher and as shown in their textbook. The two items were similar to those examined by Jitendra, Salmento and Haydt (1999) as being included in the grade 4 curriculum. Thus they seemed appropriate for this lesson.

The primary author then demonstrated an alternative algorithm, a form of which is described by Silbert, Carnine and Stein (1990). Specifically, the algorithm minimizes or eliminates *renaming* and reduces difficulties of students such as reported by Bryant and colleagues (Bryant, et al., 2000). The results are shown for two of these items by simply listing the responses to each item before and after the introduction of the alternative algorithm.

The column on the left shows performance before students were shown an alternative algorithm and the column

Table 2

Thirty Minutes More or Less

Student #	Pre	Post
	300	300
	-126	-126
1	284	174
2	233	174
3	278	174
4	284	174
5	-	174
6	206	174
7	226	174
8	084	174
9	187	not finished
10	184	174
11	184	174
12	226	174
13	284	174
14	84	174
15	174	not finished
16	174	not finished, but ok
17	174	174
18	226	174
19	94	174
20	174	174
21	174	174
22	84	174
23	174	174
# Correct/Total	6/22	20/23

Student #	Pre	Post
	4001	4001
	-2764	-2764
1	1347	1237
2	237	1237
3	337	1237
4	1235	2347
5	-	1237
6	2003	1237
7	2763	0230
8	?347	1237
9	2763	1321
10	1397	not finished, but ok
11	547	1237
12	-	7321
13	2767	1237
14	2343	1233
15	347	1233
16	-	?
17	-	2736, not finished
18	1237	1237
19	2763	1237
20	-	1237
21	47	1237
22	1237	1237
23	347	1237
24	1237	1237
# Correct/Total	3/19	15/23

on the right shows performance after the alternative algorithm was introduced. The entire activity took approximately 30 minutes. The number of students who calculated correct answers rose from 6 to 20 for the problem 300 - 126 and from 3 to 16 for the problem 4000 - 2764. What is most striking about these results is that the activity took only 30 minutes.

Figure 3 shows the work of one student with learning disabilities, one considered to be *at risk* in math and one who is normally achieving.

The alternative algorithm eliminated the need to *borrow* or *rename* and therefore, the difficulty with zero and subtraction from other place values was by-passed. In this illustration we see that the work of the three students was correct for 300 - 126 when using the alternative algorithm and that two of the students were incorrect for 4001 - 2764. A review of the errors indicates that both students concep-

A review of the errors indicates that both students concep-tualized the algorithm and one made two errors while the other made only a single error. The algorithmic error resulted when two students subtracted (i.e., 1235 - 2) instead of added and one student subtracted incorrectly (i.e., 1235 - 2 = 1231). Note that the student with learning disabilities used an incorrect algorithm in that student subtracted the smaller number from the larger number inappropriately. The student did not do this with the alternative algorithm. Thus, it would seem wise to correct the error where the students subtracted instead of added and anticipate that students who calculated incorrectly would correct the calculation. This approach is consistent with the work of Brained (1983) who suggests that even though students may give an incorrect response to an item, it does not mean they do not know how to do it.

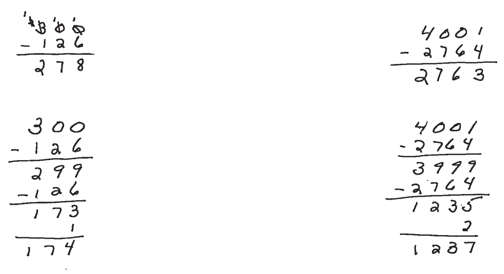
As part of the same project, a junior high school class-

Figure 3

Illustrations of Student Subtraction Performance

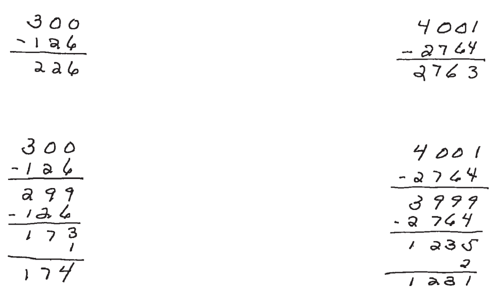
Normally Achieving Student

Before Instruction in Alternative Algorithm	After Instruction in Alternative Algorithm



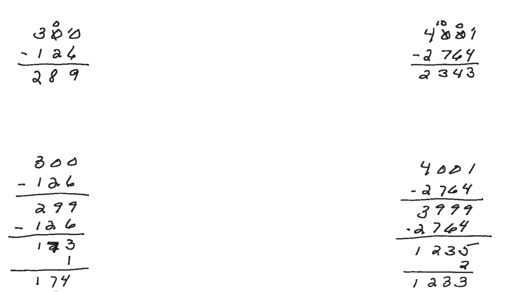
Student with Learning Disabilities

Before Instruction in Alternative Algorithm	After Instruction in Alternative Algorithm



Student with Difficulties in Mathematics

Before Instruction in Alternative Algorithm	After Instruction in Alternative Algorithm



mented the general method described above. One day the teacher called the project office as she encountered a snag with the algorithm. Project staff explained the dilemma and the teacher proceeded. The staff thought it would be a good idea to videotape the classroom as they tried to replicate their efforts to unravel the snag. The teacher agreed. However, the students were reluctant to replicate the situation and indicated that the use of the new algorithm was so *neat* that they saw no reason to practice it *the wrong way*. An interesting outcome for this classroom was that 8 of the 10 students passed the eighth grade district wide mathematics competency test. When the central office received these data, it called the results into question and sent an individual to rescore the students' tests. The results were the same as those originally reported by the teacher.

Enhancement Modifications to Mathematics

Counting, especially counting through 10 is essential for students' understanding of renaming and place value. Students need to demonstrate comprehension that each time 10 is reached, renaming, either upward or downward, is required. Students counting by 1's must be aware that each time 10 is reached, they must rename upward and comprehend that the ten 1's are now represented as one 10. Counting downward involves the inverse procedure in that going from seven 10's in an item such as 74 - 18 changes the representation from 70 + 4 to 60 + 14.

Reisman (1977) cautions against the use of expanded notation in subtraction because some children tend to misread the sign (+) which joins the expanded place values as a signal to add. Accordingly, 70 + 4 - 10 + 8 would be completed as 8 + 4 and 10 + 70. We have not had any difficulty with expanded notation and encourage its use as a means of translating object representation to symbolic representations. When presented in expanded notation format the original subtraction item looks like:

70 + 4
10 + 8

after renaming it looks like:

60 + 14
10 + 8

The combination of left-to-right and expanded notation presents a clear representation of the operation as shown below:

70 + 4
10 + 8

and with a somewhat larger number as:

500 + 60 + 6
100 + 70 + 9

Alternative Representations

There is not complete agreement in the field of special education about the importance and meaningfulness of alternative representations. The CEC standards for teachers indicate that teachers should be able to use the *concrete-representational-abstract* (CRA) sequence for teaching mathematics. The general outcome for projects using multisensory materials is similar to that of other intervention efforts in that improvement in students performance is noted using paper-pencil tests as the dependent variable (Marsh &

Table 3

Alternative Representations and Assessment (Percent Correct)

			Chronological Age				
			9	10	11	12	13
Item No. in Figure 4	Item No. in Table 4	Alt. Rep. (instruction/respose)*	N=24	N=22	N=22	N=28	N=21
1	1	w/m	75	100	95	100	95
	2	w/s	79	95	90	100	95
	3	w/m	54	72	95	85	85
	4	w/s	50	59	77	96	80
	5	w/m	41	63	85	86	80
	6	w/s	33	40	89	81	61
2	7	s/w	37	59	77	75	71
	8	w/w	29	27	54	64	47
	9	s/w	79	90	95	100	95
	10	w/w	50	77	86	92	76
	11	s/w	50	77	86	92	80
	12	w/w	25	22	54	67	66
	13	s/w	33	45	54	64	71
	14	w/w	04	18	40	46	28
3	15	w/w	04	09	18	14	19
4	16	d/s	75	90	81	100	90
	17	w/s	62	59	77	85	76
	18	d/s	58	54	81	82	76
	19	w/s	70	72	77	96	76
	20	d/s	58	54	86	85	76
	21	w/s	33	36	45	17	38
	22	d/s	41	50	72	85	66
	23	w/s	41	27	59	46	61
5	24	w/m	50	68	90	82	85
	25	w/w	37	36	77	75	80
	26	w/m	37	31	86	82	71
	27	w/w	29	22	77	50	61

* Alternative Representation: w = write, s = say, d = display, m = manipulate

Cooke, 1996; Miller & Mercer, 1993; Scott, 1993). Our thinking is that the sequence itself has yet to be validated and that an alternative position is that teachers should be able to use a variety of representations in teaching and assessment, but not in any fixed sequence. Outside of the school text the great majority of applications and use of mathematics involves transitioning from the *abstract* to the *concrete*. Examine any object in the environment (e.g., rocket ship, skyscraper, toy) and there is a near 100% likelihood that creation of that object involved a sequence from the abstract to ation of that object involved a sequence from the abstract to the concrete. The construction of a skyscraper, for example, involves the abstract preparation of architectural drawings and specifications, which are translated by builders into foundations, supports and other building components.

CRA may not be an effective sequence (Harding, Gust, Goldhawk & Bierman, 1993), nor efficient. In reality the use of alternative representations is guided by the outcomes desired of the students. If the desired student outcome is to respond to printed items by using rotely learned facts or rou-

Figure 4

Assessment Items

Item 1: Say: *See this*. [Show flash-card]
Say: *Watch me* [Make a representation with manipulatives]
*Explain what you are doing as you do it. Be certain to show the answer.
Say: *Now, I would like you to some for me*
Say: *See this*. [show flash-card with] 9
-5
Say: *Take the sticks and make this for me. Tell me what you are doing and show me the answer when you are finished*.

Item 2: Say: *I am going to say a number problem, and I want you to write it for me and show your answer.*
Say: *Seventeen minus five*.

Item 3: Say: *See this* [Show last item correct from previous section] you did this by saying [repeat what student said]. *Can you do it another way? Can you show me another way to do it?* If the student does not understand, prompt with, *Watch me* and show the left-to-right algorithm.
Say: *How about trying it with this one?* [Give one from correct responses in previous section]

Item 4: Say: *Let's try one of these.* [Show flash-card with representation of 46 - 26 as:
111111
- ## 111111
Say: *Tell me what subtraction problem this says*. As student states the item, write it and your answer on paper. Show the student what you have written and ask if it is correct. Show 57 - 35 as:
1111111
- ### 11111
and repeat the above steps. When you write this one, write the answer as 24. See if the student catches you.

Item 5: Say: *Now I will show you some problems and I want you to make them for me with these number stamps*. Provide a practice task. Show the student, 17 - 6 and have the student represent it with the number stamps. Ask the student to look at the stamp representation, complete the operation, and tell you the answer. If the student can not do it, show the flashcard of 17 - 6 and ask for the answer. Record the manner in which the student completed the item.

If, on the other hand, the desire is to have students both *know* many things about subtraction and be able to *do* subtraction in many ways, then alternative representations have a role to play. This is illustrated below.

Assessment

Table 3 displays a set of data on samples of students with mild disabilities whose assessment for subtraction included alternative representations as well as selected elements of subtraction and cognition. The data are percent correct and Figure 4 describes the items.

Items 1-6 in the Table 3 correspond to item 1 in Figure 4. Items 7-14 in Table 3 correspond to item 2 in Figure 4. Item 15 corresponds to item 3, 16-23 correspond to item 4 and 24-27 correspond to item 5. The number of items reflects different number combinations and each pair of items (e.g., 1 and 2) represent the two components of each query. Item 3 requested the students to demonstrate an alternative algorithm. The low percent correct for this item, number 15, was not expected because the students did considerable work with alternative algorithms throughout the project.

Discussion

To find justification to systemically restructure the mathematics presented to teachers and subsequently students with disabilities, one needs only examine the literature to determine the degree to which the comment by Lloyd (1997) is substantiated. The field has conducted a multitude of intervention projects in which numerous instructional variables have been examined and the results remain limited.

None of the literature clearly identifies the *big idea* or includes the big idea as a dependent variable. It is time for a change and that change calls for a re-examination of the mathematics presented to teachers and students. With respect to computation, it is essential that we move away from rote drill and practice with the traditional algorithms and turn more to *number sense* and what and how students should think about what they *know* and are *doing*. In effect, the importance of number sense as stressed by Gersten and Chard (1999) and the inclusion of *big ideas* as suggested by Carnine, Jones, and Dixon (1994) needs to be accentuated in programs for students with learning disabilities. These can readily be included in intervention research by making number sense and big ideas the dependent variables instead of rote computation.

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Neurobiological Basis of Learning Disabilities: An Update

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This paper reviews recent research in the field of learning disabilities and, in particular, developmental dyslexia. It summarizes findings from numerous studies employing widely divergent methodologies that have attempted to establish the neurobiological correlates of learning disabilities, including genetic, neuroanatomical, electrophysiological, and neuropsychological investigations. On the basis of the evidence compiled, it seems impossible to deny that learning disabilities are a manifestation of atypical brain development and/or function.

The Learning Disabilities Association of Canada convened the authors of this paper to summarize the considerable research literature that has provided evidence that learning disabilities are a neurobiologically based condition. Preparation of this paper was primarily motivated by the need to further inform people in education, politics, and social policy that learning disabilities are a condition based on atypical brain development and/or function. The understanding and acceptance of the neurobiological basis of learning disabilities is crucial to the development of programs and policies necessary to assist individuals with learning disabilities.

Important research efforts have focused mainly on developmental dyslexia, that is, reading disability, because it represents the most common and frequently identified learning disability. Reading is the primary academic problem in approximately 80% of children diagnosed with learning disabilities. Neurologically based learning disabilities represent a heterogeneous group of disorders that involve both learning and behavioral components. Although learning disabilities may be exacerbated by other variables, such as ineffective teaching strategies or socioeconomic barriers, this paper supports the position that the essence of learning disabilities is neurobiological in nature.

Historical Perspective

The association of learning disabilities with underlying neurological mechanisms has been noted in the early case studies of acquired alexia and developmental dyslexia, with the major contributions to this literature dating back to Dejerine in 1891. Alexia refers to a syndrome in which an individual who is able to read subsequently has a cerebral insult, such as a head injury or a stroke, and can no longer comprehend the written or printed word. Dejerine correlated this acquired reading deficit with pathological findings on postmortem examination, and because of this evidence, specific parts of the brain were localized as important to the task of reading. When an inability to develop fluent reading skills was initially recognized in children, it was hypothesized that the functions subserved by the same areas of the brain affected in adults with acquired alexia must be implicated somehow in children and, therefore, cause difficulties in reading skill acquisition. Difficulty in acquiring the ability to read in individuals with normal intelligence was termed *developmental dyslexia*. The left angular gyrus; the left occipital lobe; the left calcarine, fusiform and lingual cortex; and the splenium of the corpus callosum were implicated as the likely areas of brain dysfunction in children with developmental dyslexia.

Pathological findings observed in an acquired reading disorder cannot be linked directly to a developmental disability, for reasons such as neural plasticity and the possible transfer of functions from one part of the brain to another. Nevertheless, the anatomical discoveries from cases of acquired alexia in terms of localization of dysfunction, the kind and extent of reading disability and its associated neurolinguistic and neuropsychological symptoms, as well as other neurobehavioral correlations, have served as a useful model on which to base research in learning disabilities, particularly reading disabilities.

Since those early hypotheses were developed over a century ago, there has been an ever-growing body of evidence that continues to demonstrate the association of learning disabilities and neurobiological factors. This evidence includes research into the etiology of learning disabilities as well as evidence that the structure and function of the brain are related to learning disabilities.

Etiology

Genetics of Learning Disabilities

The familial nature of reading disability was first described by Thomas in 1905, and since then, pedigree analysis, sibling analysis, and twin studies have confirmed that it runs in families (e.g. Gilger, Pennington, & DeFries, 1991; Lewis & Thompson, 1992; Lubs et al., 1993; van der Lely & Stollwerk, 1996). In fact, offspring risk rates are significantly elevated if a parent reports a history of reading disability, and the risks are sufficiently increased in families with parents who have a reading disability to warrant use of family history as a component in clinical evaluation (Gilger et al., 1991). As early as 1950 (Hallgren, 1950) it was reported that when one parent was affected, on average, 46% of the children were affected by dyslexia. Thirty-four years later, Vogler, DeFries, and Decker (1984) reported essentially the same risk: if one parent was affected, 55% of the sons displayed reading deficits (though there may be reduced risk in daughters). Heritability estimates for various reading phenotypes have ranged from 0.51 to 0.93.

Results of twin studies and a comparison of monozygotic and dizygotic concordance rates have provided suggestive evidence of a substantial genetic etiology of reading disabilities. The Colorado twin study reported concordance rates of 68% for monozygotic twins and 40% for dizygotic twins (DeFries et al., 1997). The difference between identical and fraternal twins was significant, further demonstrating that reading disability is caused in part by heritable influences.

Despite the certainty of the existence of a genetic basis, the mode of inheritance has not yet been proven. Some research has supported an autosomal (not sex-linked) dominant mode of transmission; other work has indicated recessive, polygenic inheritance and genetic heterogeneity.

Potential explanatory modes of transmission of learning disabilities through genetics have been discussed in terms of three basic genetic models (e.g. Pennington & Gilger, 1996). A Mendelian genetic model stipulates that a single, major gene is responsible for a significant proportion of the variation present in reading. The multifactorial-polygenic model assumes that many genes, with additive and equal effect, act together with a variety of environmental factors to produce the range of phenotypes observed. The model of Quantitative Trait Loci posits that genes of additive but unequal effect are responsible for the heritable aspects of the variance in a phenotype such as reading. Currently, the linkage data reviewed below tend to support the latter model; namely, that a number of genes at different loci may contribute to the range of reading ability/disability and that a simple locus is not likely (Gilger et al., 1996; Pennington & Gilger, 1996).

The first molecular genetics study of dyslexia was published in 1983, and reported a linkage between reading disability and a region of chromosome 15 (Smith, Kimberling, Pennington, & Lubs, 1983); however, this finding has been disconfirmed by some (Bisgaard, Eiberg, Moller, Niebuhr, & Mohr, 1987). Subsequently, Smith, Kimberling, and Pennington (1991) added other families to their sample and reported an additional linkage for a region on the long arm of chromosome 15. Single-word reading has more recently been linked, albeit weakly, to a region on the long arm of chromosome 15 by Grigorenko and her colleagues (1997). Others have also studied this region, with both positive and negative findings.

Chromosome 1 has also attracted some attention with respect to the genetic transmission of learning disabilities. Rabin and co-workers (1993) reported suggestive evidence of linkage on its short arm, as did the Grigorenko group (1998). On the other hand, some have been unable to replicate this finding. The short arm of chromosome 2 has been implicated in a single large Norwegian family with dyslexia.

Several studies on genetics and learning disabilities have reported a susceptibility locus on the short arm of chromosome 6 (e.g. Grigorenko et al., 1997). Other researchers have failed to replicate a linkage even though both a qualitative phenotype and a quantitative measure of reading disability were applied (e.g. Petryshen, Kaplan, Liu, & Field, 2000). A new region on the long arm of chromosome 6 has also been identified (Petryshen, Kaplan, Liu, & Field, 1999), but no attempts at replication of this finding have yet been reported.

It is important to note that discrepant results in this type of research do not necessarily mean erroneous research. The increasing number of gene localizations may simply indicate the heterogeneity of the disorder, as well as the heterogeneity of the gene pools being investigated.

The gender ratio for reading disabilities may not be as disproportionate as commonly held in the past, due to under-identification of females with learning disabilities (DeFries, Gillis, & Wadsworth, 1993). Current findings indicate that the male-female sex ratio across samples averages about 1.5:1.0 (e.g. Lubs et al., 1993).

In summary, the influence of predisposing genes on the familial occurrence of dyslexia is now fully accepted, although much work is still needed to identify the contributing genes. In terms of the topic of this review paper, it is worth considering the fact that there probably are no genes that code specifically for dyslexia. It is likely that the molecular genetics findings reviewed above are particularly relevant to the language areas of the brain, yet it is still unlikely that any one of them influences reading and no other brain function. Roughly one-third of the estimated 60,000-100,000 genes in humans have some influence on the central nervous system. In view of this large number of genes, identifying those specific genes that influence learning disabilities continues to be a challenge.

In addition to the influence of genetics as an etiological factor of learning disabilities, several environmental factors also affect brain development. Prenatal, perinatal, and postnatal events, as well as toxicological, nutritional, and teratogenic effects have all been shown to impact brain development and cause learning disabilities.

Adverse Effects on Brain Development

Prenatal, Perinatal, and Postnatal Events

Many biological factors can impact brain development and result in learning disabilities. Anatomical development of a child's brain prior to birth consists of cell proliferation and migration, axon and dendritic growth, synapse formation and loss, glial and myelin growth, and neurochemical changes. Not only is the brain's early development complex, but also growth continues over a prolonged period of time. Normal cortical growth can be disrupted by a wide range of events, which influence not only early postnatal growth and development, but also later cognitive and behavioral development. The study of these events has been substantial, but methodological problems in the investigation of the fetal brain have made it difficult to determine exactly which event, or combination of events, leads to which specific outcomes.

One of the most common consequences of early insult to the developing brain is birth before full gestational age or at less than full birth weight. The studies of very low birth weight infants (VLBW) have varied along the dimension of birth weight and gestation. Generally, more favorable outcomes have been associated with higher birth weights. Some studies have indicated that VLBW children have a higher rate of learning disabilities (35%). Significantly poorer performance has been reported on a variety of measures of cognitive skills for VLBW in comparison to normal controls, including perceptual-motor and fine motor skills, expressive language, memory, hyperactive behavior, and academic achievement, including reading and arithmetic (e.g. Saigal, Hoult, Streiner, Stoskopf, & Rosenbaum, 2000). As well, learning disabilities were less related to the more typical language-based learning disabilities than to arithmetic, perceptual motor, and attentional areas (e.g. Taylor, Hack, Klein, & Schatschneider, 1995).

Other studies on early brain development have attempted to isolate the specific effects of related medical complications, specifically, bronchopulmonary dysplasia, which is oxygen dependence at or beyond 36 weeks gestation; perinatal asphyxia; intraventricular hemorrhage; and hydrocephalus. Children with these medical complications were demonstrated to be at risk for neurodevelopmental compromise and a variety of cognitive and academic difficulties. Transient Neonatal Hypothyroxinemia may also contribute to learning disabilities.

Research has also been conducted on the effects of neonatal seizures on neurodevelopment and later outcomes. Neonatal seizures in the first four weeks after birth are among the most common neurological emergency. They may be indicative of subtle neurodevelopmental vulnerability which may arise, at a later point, as a specific learning disability, with demonstrated difficulties in spelling and arithmetic as well as memory impairment for visual material (Temple, Dennis, Carney, & Sharich, 1995).

Many studies have used retrospective designs to determine correlations between perinatal events and later outcomes. Two specific categories of perinatal events that best predicted school achievement were gestational age and obstetrical history. Severe perinatal complications were significantly related to problems in cognitive and motor development.

Toxins, Nutrition, and Teratogens

Many toxic agents are known to damage the developing, and unprotected brain by interfering with those processes undergoing development at the time of the exposure. Compared to the adult brain, the possibility that the developing brain is differentially sensitive to environmental agents was highlighted in a report by the US National Research Council on pesticides in the diets of infants and children (1993). Loss of cells (microneurons) generated late in pregnancy is significant, because these cells are essential for establishing the balance between inhibitory and excitatory activities in critical brain areas such as the hippocampus (Morgane et al., 1993). Unlike other organ systems, the unidirectional nature of central nervous system development limits the capacity of the developing tissue to compensate for cell loss during specific time frames.

Thyroid hormones regulate neuronal proliferation, migration, process outgrowth, synaptic development, and myelin formation in specific brain regions and are essential for normal behavioral, intellectual, and neurologic development (Porterfield, 2000). Resistance to Thyroid Hormone, is one of several hormone resistance syndromes which has been identified via molecular genetic studies and associated with poor school performance, learning disabilities, and symptoms of hyperactivity (Hauser, McMillin, & Bhatara, 1998). Maternal and/or fetal thyroid deficiency in utero has also been linked to poor performance on neuropsychological tests (e.g. Haddow, et al., 1999).

Polycholorobiphenyls (PCBs) and other dioxin-like compounds can affect neurodevelopment and learning, in that, they bear a striking resemblance to active thyroid hormones, can mimic or disrupt their actions, and are known to cross the placenta and reach the fetus. Prenatal exposure to PCBs has been associated with weaker reflexes at birth and less responsiveness, and with poorer visual recognition memory; delays in reading comprehension, problems in attention, planning, and organization; and lower IQ scores (e.g. Jacobson & Jacobson, 1996). Neonates whose mothers had higher exposures to contaminants in fish had lower scores on neonatal assessment measures. High cord blood PCB levels were found to be predictive of lower performance on cognitive measures. (Darvill, Lonky, Reihman, Stewart, & Pagano, 2000).

The neuropsychological and cognitive effects of low-lead exposure have been demonstrated since 1979. Since that time a number of studies have found long-term effects from early exposure to lead (Feldman & White, 1992).

Blood lead measured in the early postnatal period was the strongest predictor of effects on school age IQ. The increased absorption of lead in children may be a factor in attentional problems and aggressiveness and for delinquency (e.g. Needleman, McFarland, Ness, Tobin, & Greenhouse, 2000). A study using data from the National Health and Nutrition Examination Survey-III found an inverse relationship between blood concentration levels as low as 2.5 micrograms per deciliter (μg/dL) and cognitive function scores (Lanphear, Dietrich, Auginger, & Cox, 2000). (Ten μg/dL is currently the alert level for lead toxicity.)

The major classes of pesticides are inherently neurotoxic and can affect the developing brain. The first study to look at the possibility of effects from exposure to pesticides indicated that children from the agrarian regions in Mexico where pesticides were used had difficulty with eye-hand coordination, memory, and social and emotional competence, as well as weakened stamina compared to matched control children from areas with very low pesticide use (Guillette, 1998).

Alcohol has been found to have a significant impact on brain development in utero in several studies. Lower performance on IQ tests has been associated with two or more alcoholic drinks a day in mid-pregnancy (e.g. Carmichael Olson, Sampson, Barr, Streissguth, & Bookstein, 1992), and 80% of clinically diagnosed young adults with Fetal Alcohol Syndrome were found to have attentional deficits (LaDue, Streissguth, & Randels, 1992). Significant deficits in sequential processing, mental composite scores, and academic skills have been reported in children who were exposed throughout pregnancy from low to moderate amounts of alcohol (11.80 oz. per week). Behavioral problems in play and social interaction as well as attentional deficits were found with moderate amounts of alcohol intake during pregnancy. A recent experimental animal study found that ethanol administered in just two doses, hours apart, during the time of synaptogenesis, resulted in a massive loss of neurons in the rat forebrain (Ikonomidou, et al., 2000). This would coincide with fetal exposure during the last trimester of pregnancy.

The developmental effects of cigarettes, marijuana, and cocaine have been examined in several large prospective studies. Maternal smoking has been associated with altered auditory functioning and reading, impulsive behavior (Fried, Watkinson, & Gray, 1992), lower IQ scores (Olds, Henderson, & Tatelbaum, 1994), and behavior problems (Weitzman, Gortmaker, & Sobol, 1992). Prenatal marijuana exposure was related to increased omission errors in vigilance. The research on the effects of cocaine use in pregnancy has given mixed results; one study suggested multiple-risk outcomes, including disruption in the discourse-pragmatics of language. (Mentis & Lundgren, 1995).

Several studies have investigated the effects of malnutrition and undernutrition on cognition and behavior. Dietary precursors of neurotransmitters are critical to their regulation, and production and imbalances of neurotransmitters have been implicated in a number of conditions, including aggression, learning disabilities, and irritability. Malnutrition has been shown to result in a number of syndromes involving attentional processes, adaptability, and learning disabilities (Morgane et al., 1993). Iron deficiency has been linked to negative effects on development, IQ, and achievement test scores, which persist into childhood, even after supplementation. Several studies have followed children who were chloride deficient. Most of these children showed a neurobehavioral syndrome of language disorder as well as other academic and social deficits, despite average intellectual capability. Nutritional factors can affect, although not abolish, the response to toxic exposures. Children who are deficient in calcium and iron are more susceptible to lead toxicity.

In summary, research in the fields of developmental toxicology, environmental epidemiology, and nutrition present an important facet of etiology and, significantly, an opportunity for prevention of some learning disabilities.

In addition to the research into brain development, measurement of brain structure and function has provided information and a further understanding of the neurobiological basis of learning disabilities.

Measurement of Brain Structure and Function

Neuroanatomical Studies

Neuroanatomical investigations of brain morphology have provided strong evidence that there are differences in the brains of individuals with dyslexia (or reading disability) versus those without problems in reading (normal controls). Included in this category of investigation are postmortem or autopsy studies of the cytoarchitectonic features of the brain. Structural and functional neuroimaging techniques have also been applied to investigate these differences.

Autopsy Findings

In autopsy research, Galaburda and his colleagues have been the main contributors to this area of investigation (e.g. Galaburda, 1997; Galaburda & Livingstone, 1993). These researchers have found areas of symmetry and asymmetry in normal brains that differ in individuals with reading disabilities. The autopsied brains of individuals with dyslexia show alterations in the pattern of cerebral asymmetry of the language area, with size differences and minor developmental malformations that affect the cerebral cortex.

The planum temporale is an area of the temporal lobe known to be language-relevant in normal controls. The planum temporale lies on the supratemporal plane deep in the Sylvian fissure and extends from the posterior border of Heschl's gyrus to the bifurcation of the Sylvian fissure. It is believed to consist cytoarchitectonically of secondary auditory cortex (Shapleske, Rossell, Woodruff, & David, 1999). The work of Galaburda and colleagues has shown that about two-thirds of normal control brains show an asymmetry; the planum temporale of the left hemisphere is larger that that of the right hemisphere. Between 20% and 25% of normal control brains show no asymmetry, with the remaining having asymmetry in favor of the right side (Best & Demb, 1999). This asymmetry is thought to be established by 31 weeks of gestation.

In contrast, the brains of reliably diagnosed cases of developmental dyslexia have shown the absence of ordinary asymmetry; symmetry is the rule in the planum temporale of brains of dyslexic subjects studied at autopsy, and increased symmetry has also been found in imaging studies (e.g. Best & Demb, 1999). These findings are relevant, since individuals with dyslexia have language-processing difficulties, and reading is a language-related task. Therefore, anatomical differences in one of the language centers of the brain are consistent with the functional deficits of dyslexia.

Because abnormal auditory processing has been demonstrated in individuals with dyslexia (as discussed later), accompanying anatomical abnormalities in the auditory system have also been the focus of autopsy studies, specifically in the medial geniculate nuclei (MGN), which are part of the metathalamus and lie underneath the pulvinar. From the MGN, fibers of the acoustic radiation pass to the auditory areas in the temporal lobes. Normal controls showed no asymmetry of this area, but the brains of individuals with dyslexia showed that the left side MGN neurons were significantly smaller than those on the right side. Also, there were more small neurons and fewer large neurons in the left MGN in individuals with dyslexia versus controls (Galaburda & Livingstone, 1993). These findings are of particular relevance in view of the left hemisphere-based phonological deficit in individuals with dyslexia (Tallal, Miller, & Fitch, 1993).

Neuroanatomical abnormalities in the magnocellular visual pathway have been reported (Galaburda & Livingstone, 1993), and these have been postulated to underlie functioning of the transient visual system in individuals with reading disabilities. Jenner, Rosen, and Galaburda (1999) concluded that there is a neuronal size difference in the primary visual cortex in dyslexic brains, which is another anomalous expression of cerebral asymmetry (similar to that of the planum temporale) which, in their view, represents abnormal circuits involved in reading.

In addition to the asymmetries anomaly, autopsy studies have also revealed multiple focal areas of malformation of the cerebral cortex located in the language-relevant perisylvian regions (Galaburda, 1989). The perisylvian cortices found to be affected by the minor malformations include the following: the frontal cortex (both in the region of and anterior to Broca's area), the parietal operculum, the inferior parietal lobule, and the temporal gyrus. Studies have shown that when scarring was dated according to the stages of brain development, it was determined that the abnormality in development had occurred sometime between the end of pregnancy and the end of the second year of life (e.g. Humphreys, Kaufmann, & Galaburda, 1990). These findings have been related to experimental animal research. According to Galaburda, symmetry may represent the absence of necessary developmental pruning of neural networks, which is required for specific functions such as language. In other words, the pruning which takes place in normal controls does not take place in individuals with dyslexia (Galaburda, 1997), thereby resulting in atypical brain structures, which are associated with language-related functions.

Structural Neuroimaging Techniques

Magnetic Resonance Imaging (MRI) studies have substantiated the findings of autopsy studies; namely, individuals with dyslexia do not have the asymmetry or the same patterns of asymmetry of brain structures that is evident in individuals without dyslexia. A number of investigators have demonstrated a high incidence of symmetry in the temporal lobe in individuals with dyslexia (e.g. Best & Demb, 1999; Logan, 1996; Rumsey et al., 1996). Duara and co-workers (1991) and Larsen, Høien, Lundberg, and Ødegaard (1990) showed a reversal of the normal leftward asymmetry in the region of the brain involving the angular gyrus in the parietal lobe. Dalby, Elbro, and Stodkilde-Jorgensen (1998) demonstrated symmetry or rightward asymmetry in the temporal lobes (lateral to insula) of the dyslexics in their study. Further, the absence of normal left asymmetry was found to correlate with degraded reading skills and phonemic analysis skills.

Logan (1996) reported that individuals with dyslexia had significantly shorter insula regions bilaterally than controls. Hynd and co-workers (1995) identified asymmetries in the genu of the corpus callosum of individuals with dyslexia and positively correlated both the genu and splenium with reading performance. This supports the hypothesis that, for some individuals with dyslexia, difficulty in reading may be associated with deficient interhemispheric transfer. Hynd and his colleagues also reported shorter insula length bilaterally and asymmetrical frontal regions in individuals with dyslexia. The latter was related to poorer passage comprehension. Best and Demb (1999) examined the relationship between a deficit in the magnocellular visual pathway and planum temporale symmetry. They concluded that these two neurological markers for dyslexia were independent.

There has been substantial replication of findings, particularly with respect to the planum temporale. On the other hand, there have been conflicting reports regarding other areas, especially the corpus callosum (Hynd, et al., 1995 versus Larsen, Høien, & Ødegaard, 1992). Methodological and sampling differences, such as slice thickness, orientation and position, and partial volume effects may account for this variability. In a review of the literature on the planum temporale, Shapleske ad co-workers (1999) summarized the methodological concerns in operationalizing consistent criteria for anatomical boundaries when measuring the planum temporale and the need to use standardized measures of assessment and operationalized diagnostic criteria. They concluded that dyslexics may show reduced asymmetry of the planum temporale, but studies have been confounded by co-morbidity. Despite a multitude of developmental factors influencing the final size, total corpus callosal size is implicated in reading disabilities. In a study by Robichon and Habib (1998), in which more rigid methods were applied, MRI and neuropsychological findings of dyslexic adults were correlated and compared with normal controls. Different morphometric characteristics were positively correlated with the degree of impairment of phonological abilities. The corpus callosum of the dyslexic group was more circular in shape and thicker, and the midsagittal surface was larger, particularly in the isthmus.

Pennington (1999) summarized the findings of a structural MRI study of brain size differences in dyslexia, reportedly the largest dyslexic sample yet studied, in which he and his colleagues investigated 75 individuals with dyslexia and 22 controls involving twin pairs. The insula was significantly smaller, the posterior portion of the corpus callosum (isthmus and splenium) was marginally smaller, and the callosal thickness was smaller. On the basis of a preliminary test within twin pairs discordant for dyslexia, it was suggested that these size differences in the insular and posterior corpus callosum were not specific to dyslexia, but rather represented a neuroanatomical difference in dyslexic families. Further, it was concluded that genetic influences play a dominate role in individual differences in brain size. The importance of controlling variance due to gender, age, IQ, and Attention Deficit/Hyperactivity Disorder was emphazized by Pennington. He did not find clear evidence of differences in the corpus callosum in a group with reading disabilities. In view of the consistencies, more research to clarify the findings was recommended.

Functional Neuroimaging Techniques

Functional neuroimaging techniques, including positron emission tomography (PET), regional cerebral blood flow (rCBF), functional magnetic resonance imaging (fMRI), and single photon emission computed tomography (SPECT) have added a unique dimension to the study of the neurobiological basis of learning disabilities, by measuring the activity in the brain of individuals with dyslexia while they are engaged in reading tasks. These are therefore in vivo studies of the brain. Using this method, atypical brain activity in specific areas has been identified and directly correlated with developmental language disorders and reading subskill functions.

Potentially confounding variables are associated with functional neuroimaging investigations, especially when studying young children. These include such factors as the effects of task difficulty in relation to developmental level of the subjects, necessity to account for changes in brain size and shape with development, as well as technical difficulties in providing a suitable testing environment for children. Regardless, impressive data have been collected. A significant difference in cerebral blood flow in children diagnosed with dyslexia has been reported (e.g. Flowers, 1993). In these studies, controls showed activation to the left superotemporal region corresponding to Wernicke's area, whereas the group with reading disabilities showed activation of the immediately posterior temporoparietal region. Interestingly, the cerebral blood flow patterns of remediated subjects with dyslexia did not differ from those of subjects with persistent impairment.

An association between dyslexia and phonological awareness deficits has been demonstrated (Flowers, 1993; Paulesu, et al., 1996). Shaywitz and colleagues (1998) reported differential brain activation patterns in dyslexic and normal readers engaged in phonological analysis tasks of increasing complexity. The dyslexic readers showed relative underactivation of Wernicke's area, the angular gyrus, the extrastriate and striate cortex (posterior regions), and overactivation of the inferior frontal gyrus (anterior region). The researchers concluded that their findings provided neurobiological evidence of the critical role of phonological analysis in dyslexia.

Functional imaging studies have shown gender differences in patterns of brain activation during phonological processing and that separation of males and females is required in future studies. There have been a number of findings of differences in individuals with reading disabilities. Hagman and colleagues (1992) reported significant differences in the medial temporal lobe with PET studies, and Logan (1996) indicated that individuals with dyslexia had significantly higher glucose metabolism in the medial left temporal lobe and a failure of activation of the left temporoparietal cortex.

In a PET scan study, Horwitz, Rumsey, and Donohue (1998) demonstrated that in normal adult readers there was a correlation of regional cerebral blood flow in the left angular gyrus and flow in the extrastriatal, occipital, and temporal lobe regions during single word reading. In men with dyslexia, the left angular gyrus was functionally disconnected from these areas. Gross-Glenn and colleagues (1991) found regional metabolic activity measured with PET scan to be similar in individuals with dyslexia and those without dyslexia, reflecting that reading depends on neural activity in a widely distributed set of specific brain regions. There were also some differences concentrated in the occipital and frontal lobe regions. In contrast to controls, individuals with dyslexia showed little asymmetry. These findings correspond well with the reduced structural posterior asymmetry observed in the CT scan and postmortem studies. Prefrontal cortex activity was also symmetrical in individuals with dyslexia versus asymmetrical in normal controls. Higher metabolic activity (local utilization rate for glucose) in the lingual area (inferior occipital regions bilaterally) was reported by Lou (1992) with PET studies, and a single photon emission computed tomography (SPECT) scan showed striatal regions as hypoperfused and, by inference, underfunctioning.

A significant difference in rCBF activation in the cerebellum during motor tasks in a group of dyslexic adults has been demonstrated. It was concluded that cerebellar deficits alone could not account for the reading disability but adversely affected acquisition of automatic, overlearned skills. An fMRI investigation supported the autopsy findings of abnormalities in the magnocellular pathway and implied a strong relationship between visual motion perception and reading (Demb, Boynton, & Heeger, 1998).

Rumsey (1996) reviewed functional neuroimaging studies of individuals with dyslexia compared to controls. All of the studies reported some differences in brain activity, and the differences were found in multiple brain sites. Wernicke's area, the temporoparietal junction, the lingual gyrus, the left insula, posterior perisylvian area, and ventral visual pathway have been implicated.

Pennington (1999) has cautioned that the interpretation of these functional neuroimaging studies remains ambiguous, since the identified differences in brain activity could be secondary to dyslexia, or dyslexia could be secondary to the brain activity differences, or both dyslexia and the activity difference could be caused by a third factor. Pennington considered that differences in brain activation may be an indication of greater effort by the dyslexic group, may represent a compensatory strategy, or may reflect impaired processing capacity. Therefore, establishing causal links with this methodology is difficult. Nevertheless, it is apparent that there are significant differences in brain activity in individuals with dyslexia in comparison to normal readers.

In summary, neuroanatomical investigations have substantiated what had been surmised from the early traditional studies of acquired brain lesions and associated changes in functions and have brought forward new evidence to support the neurobiological basis of learning disabilities. Advances in neuroimaging have permitted brain dissection in vivo, a transparent window of brain functions, concurrent with neurological and neuropsychological evaluations. This methodology has supported previous findings and hypotheses while providing new evidence of brain structure/function relationships. Although the neuroanatomical correlates of dyslexia do not answer the question about whether dyslexia is a condition at one extreme in the normal distribution of reading skill, the neuroanatomical and neuroimaging studies have provided evidence linking learning disabilities to neurobiological etiology. Electrophysiological investigations, although less isomorphic, have also substantiated this association.

Electrophysiological Studies

Numerous variations in cortical and subcortical electrophysiological measurement techniques have been employed in the study of brain-behavior relationships of individuals with learning disabilities. Measurement strategies have included auditory, brain stem evoked responses (ABR), EEG/Power spectral analysis, cortical evoked responses (ERPs) and, more recently, magnetoencephalography (MEG). Although the latter is not purely an electrophysiological recording technique, it does involve the detection and localization of small magnetic fields associated with intracranial electromagnetic activity.

ABR studies have generally not yielded significant data, and there have been methodological weaknesses associated with these studies. With the advent of more powerful computing and statistical procedures, however, quantitative analysis of electroencephalographic recordings has shown promise as an investigative research tool. For example dyslexic children exhibited more energy in the 3-7 Hz band in the parieto-occipital region during rest conditions (e.g. Sklar, Hanley, & Simmons, 1973). This finding was replicated in a number of independent studies, but these studies were criticized for methodological reasons, and subsequently, there have been conflicting reports (Fein, et al., 1986).

In contrast, significant results have been found in studies using quantitative EEG methods, which examined carefully screened subtypes of individuals with learning disabilities while they carried out specific tasks. Dyslexic children with dysphonemic-sequencing problems showed an increase in alpha during a phonemic discrimination task, suggesting relatively poor orientation to the external stimuli. These children also showed a decrease in beta, suggesting differences in information processing in contrast to normal controls. The increased alpha-decreased beta was more evident over the left posterior quadrant, implicating the posterior speech region around Wernicke's area. Proportionately less left hemisphere 40 Hz activity for a group with reading-disabilities, in contrast to normal controls or a subgroup with arithmetic-disabilities, was found, and conversely, the subgroup with reading disabilities exhibited proportionately less 40 Hz right-hemispheric activity than the subgroup with reading-disabilities during a nonverbal task (Mattson, Sheer, & Fletcher, 1992).

Several recent, well controlled, cortical evoked potential studies have shown significant differences on the P_3 waveform, with subjects with reading disabilities having a longer P_3 and smaller amplitude to the target stimuli when compared with controls. A larger amplitude for normal controls versus children with learning disabilities was demonstrated for a negative wave at 450 ms. in response to single words during initial learning and the same words in a subsequent recognition memory test series. Similar results on a lexical task, involving distinguishing word pairs that rhymed or did not rhyme, have been reported. The language-dominant hemisphere was found to be more involved in a reading task when a probe technique was used. With difficult reading material, groups with reading disabilities generated a large bilateral central and parietal decrease in P_3 as they changed from easy to difficult material. (Johnstone, et al., 1984).

Although there is some emerging consensus from the ERP literature that phonological awareness is critical in the acquisition of reading and spelling, there remain some fundamental differences as to whether phonological processing problems are problems in their own right or whether these are due to a more fundamental sensory information processing difficulty (e.g. a temporal order information processing deficit). For example Schulte-Körne and co-workers (1998) concluded that dyslexics have a specific phoneme-processing deficit. This finding could help to identify children, at risk, as early as the preschool years. In contrast, Kujala and co-workers (2000) presented evidence, observed in their sample of adults with dyslexia, which they suggest provides support for a more fundamental temporal information processing deficit.

Research using auditory cortical evoked response technology has also yielded significant findings. Molfese and Molfese (1997) recorded neonatal auditory evoked potentials within 36 hours after birth to different sound contrasts. These same children, at follow up, were successfully classified into three language skill levels at 3 and 5 years of age, with 81% accuracy. This is a very impressive finding, since other perinatal predictors of later performance, e.g., Apgar score, the Brazelton Neonatal Assessment Scale, and low birth weight, were less effective as predictors of long-term developmental outcome.

Recently, research using MEG has uncovered interesting findings. MEG works on the principle that very weak magnetic fields are detected by means of an array of superconducting sensors. The superconductivity is preserved only at very low temperatures. These sensors are immersed into a helmet-shaped container of liquid helium that is brought close to the head for data collection. Salmelin, Service, Kiesila, Utela, and Salonnen (1996) used whole-head MEG to track the cortical activation sequence during visual word recognition in individuals with dyslexia and controls. Within 200-400 msec. following stimulus onset, the left temporal lobe, including Wernicke's area, became involved in controls but not in individuals with dyslexia. The individuals with dyslexia initially activated the left inferior frontal cortex (suggesting involvement of Broca's area). Interestingly this area has been reported to be involved when normal subjects are required to perform a silent noun generation task. The authors suggested that individuals with reading impairment, in order to compensate for their underdeveloped phonological skills, try to guess the word from whatever other limited information there may be available to them.

The usefulness of various electrophysiological and magnetoencephalographic measurement techniques is variable and a function of the type of technique employed as well as how well the targeted behavior or cognitive process, under study, has been operationally defined. Although many of the research studies can be criticized for methodological problems, the advances made in the measurement of higher cognitive functions over the past two decades have been impressive. Generally, methodologically sound studies which have examined discrete skills in carefully selected subtypes of people with learning disabilities have yielded results consistent with neuroanatomical and neuroimaging data.

Neuropsychological Studies

Neuropsychological investigations of learning disabilities have been based on psychometric testing of a variety of cognitive, sensory, motor and behavioral/emotional functions. These functions have been correlated with other types of measures of brain structure and function. This research, therefore, has provided a greater understanding of the neuropsychological profile of individuals with learning disabilities and also indirect evidence of underlying cerebral dysfunction. Within the neuropsychological literature, considerable attention has been focused on problems with either the acquisition of reading (developmental dyslexia) or math (dyscalculia) skills; the vast majority of investigations have focused on reading disabilities.

Deficient phonological awareness is now viewed as a primary problem in developmental dyslexia. Evidence from neuroimaging (fMRI, PET, and SPECT scans) and electrophysiological studies has shown that the brains of those with reading disabilities respond differently from those of control subjects, particularly on tasks involving phonological awareness. Weaknesses in the activation of motor articulatory gestures may account for the difficulty in grapheme-to-phoneme conversion, which in turn impairs the development of phonological awareness. Dysfunctions of the central auditory system and temporal information processing deficits in both the auditory and visual modalities have also been identified. Independent deficits in speech and non-speech discriminative capacity have been reported as a significant factor in reading disabilities (Studdert-Kennedy & Mody, 1995). The critical work of Tallal, Miller, and Fitch (1993) has provided evidence of a basic temporal processing impairment in language-impaired children that affects speech perception and production and is thought to result in these phonological processing deficits.

Irregular neurophysiological dynamics of the visual system may account for the random omissions and insertions of individuals with dyslexia during the reading process. Differences in the control of saccadic eye movements have been found between individuals with dyslexia and controls (Lennerstrand, Ygge, & Jacobsson, 1993). A slow rate of processing of low spatial frequency information in the magnocellular channel of the lateral geniculate nucleus has been proposed as one deficiency accounting for some reading disabilities (e.g. Chase, 1996). These results are consistent with the neuroanatomical findings. In the normal reader, the magnocellular pathway processes information more rapidly than the parvocellular route, providing the cortical maps with the global pattern information before information about the finer visual details arrives via the parvo pathway. When low spatial frequencies are processed too slowly, the ability to make rapid visual discriminations and to establish internal representations of letters and grapheme clusters in lexical memory is critically affected. This low spatial frequency deficit hypothesis has been supported by various studies (e.g. Chase, 1996; Stein, 1996). It has been speculated that abnormality of the magnocellular system is not limited to the visual modality but is generalized, affecting the auditory, somesthetic, and motor systems (Stein, 1996).

Numerous studies have attempted to identify the neurobiological basis of learning disabilities in terms of left, versus right, hemisphere dysfunction. Adult strokes were found to affect cognitive abilities such as reasoning, perceptual speed and memory clusters, scholastic aptitude, written language, reading, language or verbal learning, and arithmetic processing. It is hypothesized that, as a result of genetic or epigenetic hormonal and/or immunological factors, the cortical language areas are disturbed in their development through migration disorders and abnormal asymmetry, such that normal left hemisphere dominance does not develop, resulting in dyslexia in some children (Njiokiktjien, 1994).

Right hemisphere dysfunction has also been associated with specific learning disabilities. Damage to the right hemisphere in adults is associated with deficits in social skills, prosody, spatial orientation, problem solving, recognition of nonverbal cues, impaired comprehension and production of affective signals, and higher-order cognition about social behaviors. The right hemisphere is therefore implicated in the processing of social-emotional information in the same way that the left hemisphere is specialized for language.

The association of chronic social difficulties coupled with deficits in producing and comprehending emotional expressions, in combination with left-hemibody signs, has been reported as the right hemisphere deficit syndrome. Lower reading performance has also been associated with the right hemisphere, as have mathematical problems, and visuospatial deficits.

With regard to arithmetic disabilities, both the right and left hemispheres have been implicated. In the child, early damage or dysfunction in the right or left hemispheres has been reported to disrupt arithmetic learning, with very profound effects resulting from early right hemisphere insults, whereas in the adult, left hemisphere lesions predominate in the clinico-pathological analysis of acalculia or computation difficulty.

Several subtypes of reading disabilities have been reported (e.g. Fiedorowicz & Trites, 1991). Research has shown that the locus of an abnormality in the brain is significant, in that, abnormalities in different areas of the brain relate to different reading problems. Therefore, the reason that one individual has difficulty reading may not be the same reason as another individual.

Not only have different subtypes of reading disabilities been identified, but also different learning disabilities, including the nonverbal learning disability (NLD) subtype (e.g. Rourke & Fuerst, 1996). Individuals with nonverbal learning disabilities typically have well developed auditory perception (including phonological awareness) and simple motor skills, but have primary neuropsychological deficits involving visual perception, tactile perception, and complex psychomotor skills and psycho-social functioning, as well as difficulties in processing novel information (e.g. Rourke & Fuerst, 1996). This pattern of strengths and deficits has now been identified in individuals with a wide variety of congenital and developmental disorders and is associated with diffuse brain dysfunction, leading some researchers to speculate that it is characteristic of white matter disease or dysfunction.

Some specific areas of dysfunction have been identified in association with developmental dyslexia, namely, frontal lobe dysfunction, underlying immaturity in the myelination within the central nervous system, left temporal lobe dysfunction, and cerebellar impairment. The attentional problems associated with some cases of learning disabilities appear to have a widely distributed neurobiological basis ranging from the brainstem reticular activating system to the basal ganglia and on into the frontal cortex.

In summary, these investigations have demonstrated that neuropsychological characteristics are associated with learning disabilities. They offer indirect evidence of localization of dysfunctions which is consistent with the neuroanatomical, neuroimaging, and electrophysiological findings.

Conclusion

Recent advances in neuroscience technology as well as the development of innovative research designs have enabled scientists to answer some intriguing questions involving brain-behavior relationships. Of particular relevance to this review is the compelling scientific evidence in support of the neurobiological basis of learning disabilities. Studies employing widely divergent methodologies, e.g., research using genetic analysis, neuroanatomical neuroimaging, electrophysiological recording, pathological analysis of brain tissue at autopsy, and neuropsychological evaluation, have yielded highly convergent conclusions in support of a neurobiological etiology. The fields of behavioral toxicology and teratology have provided evidence that biological factors can negatively affect brain development, brain functioning, and subsequent learning and behavioral abilities.

It would be a formidable task to review every study that demonstrates the neurobiological basis of learning disabilities: instead, for this paper, the literature was reviewed from many perspectives to demonstrate the breadth of the available evidence that bears on this subject. Although there are still many unanswered questions, it seems impossible to deny that learning disabilities are a manifestation of atypical brain development and/or function.

The effective treatment of any condition or disease must be based on an adequate understanding of the etiology and genesis of that condition. Appreciating the neurobiological basis can facilitate the development of effective educational programs, with instructional goals, content, and pace of delivery designed to maximize success for individuals with learning disabilities. However, public policy makers have been slow to recognize the implications of this fact for the field of learning disabilities.

Recognition of the neurobiological basis of learning disabilities does not necessarily lead to a bleak outlook, because the individual's environment has the potential to reduce or amplify the impact of the learning disabilities. Supportive care-giving (Kopp, 1990), quality of the home environment (Kalmar, 1996), and socioeconomic factors (Werner, 1990), as well as educational programs designed specifically to meet the needs of individuals with learning disabilities (Fiedorowicz & Trites, 1991; Lerner, 1989), have the power to mitigate the academic and cognitive deficits associated with the condition.

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The Use of Tobacco, Alcohol, and Marijuana by Mexican American Adolescents with Learning Disabilities: A Longitudinal Study of Selected Risk Factors

David S. Katims, Zenong Yin, and Jesse T. Zapata

This longitudinal study was designed to examine the causal effects of distal (at year one of the study) and proximal (at year three of the study) risk factors for the use of *gateway* substances (cigarettes, beer, liquor, and marijuana) by Mexican American adolescents identified with learning disabilities. Distal risk factors consisited of peer deviance/delinquency, school satisfaction, self-esteem, language acculturation, and socialization acculturation. Proximal risk factors included self-reported deviance/delinquency, availablilty of substances in the school and/or neighborhood, and positive attitudes toward substance use. Findings indicate peer deviance/delinquency and socialization acculturation (social activities related to the dominant American society) are powerful risk factors for substance use by this group of adolescents.

One of the major themes of the nineteenth Annual Report to Congress on the Implementation of the Individuals with Disabilities Education Act (IDEA) focuses on the rising prevalence of substance use (cigarettes, alcohol, and marijuana) in American schools in general, and by students with disabilities in particular (US Department of Education, 1997; PL 105-17, 1997). The report describes substance use as particularly salient for students with disabilities, but intricately complex in light of their special education, social, emotional, and general learning needs (U.S. Department of Education, 1997).

According to the report, marijuana use is on the rise among all secondary students, with particular emphasis on this pattern of increasing use for 8th grade and 10th grade youth. The Office of Special Education and Rehabilitative Services (OSERS) however pointed out that relatively little attention has been given to the use of licit and illicit substances by youth identified with disabilities, particularly those having specific learning disabilities (Leone, 1991; Moore & Polsgrove, 1991; Waldie & Spreen, 1993). This is surprising given that students identified with specific learning disabilities now account for more than fifty-one percent (2,676,299 of the 5,235,952) of all school age students served under the most current revision of federal special education law (US Department of Education, 1997).

A number of studies (e.g., August, Stewart, & Holmes, 1983; De Olbidia, & Parsons, 1984; De Olbidia, Parsons, & Yohman, 1983; Hechtman, Weiss, & Perlman, 1984) have reported more substance use among students identified as having minimal brain dysfunction, attention-deficit disorder, hyperactivity, or learning disabilities than among students not so diagnosed. Karacosta and Fisher (1993) report a significantly higher proportion of adolescent students with learning disabilities than thos without learning disabilities were found to use *gateway substances* (e.g., tobacco, alcohol, and marijuana), and including hard drugs. Maag, Irvin, Reid, and Vasa (1994) investigated the prevalence of tobacco, alcohol, and marijuana use in a sample of students with and without learning disabilities and found that substance use was proportionally higher for adolescents with learning disabilities. Missing from the research literature is a longitudinal analysis of risk factors pertaining to the use of substances by this population. In addition, ethnicity, and the relevant variable of acculturation are factors seldom considered in investigations of a learning disability/substance use link. Although Hispanic Americans account for 14.2% of the school age population in the United States, 15.8% of them have been identified as having specific learning disabilities under federal law (US Department of Education, 2000).

The concept of acculturation of Hispanics in American society is an enormously important idea in the context of an intraethnic-focused study. The degree to which a person from a particular cultural group displays behaviors, ideals, and values like the more pervasive American norms is called acculturation. Portes and Zhou (1993) believe that acculturation is a discontinuous and idiosyncratic process, rather than a monolithic one, aptly described as *segmented assimilation*. This perspective provides a useful backdrop for understanding the behaviors of adolescents from minority groups. For example, Vega and other researchers (Bur- nam et al, 1987; Ebin, et al., 2001; Vega & Gil, 1999; Vega, Hough, & Romero, 1983) have found that more highly acculturated Hispanic adolescents are at-risk for substance use compared to less-acculturated adolescents. Factors pertaining to psychological resiliency, striving for acceptance by a dominant peer group, and possible stress caused by language differences between adolescents and their parents and grandparents, all play a role in the process of acculturation.

A proximal-distal approach (Agnew, Thompson, & Gaines, 2000; Allport, 1954; Glasgow, Crosnoe, & Dornbusch, 2000) was applied to theorize the impact of risk factors for substance use in the current study. Risk factors were hypothesized to have various degrees of proximity to the risk of substance use. For the present study, factors were considered *distal* if they were biological, based on early experience or preexisting in relation to the use of substances and were considered as *proximal* if they were concomitant and situational in relation to the use of substances. In general, proximal factors have more immediate influence on the use of substances and therefore are better predictors of the use of substances compared to distal factors (Agnew, et al., 2000). Although it is not necessary, the effects of distal factors are often manifested or mediated via their influence on the proximal factors (Agnew, et al., 2000; Glasgow, et al., 2000). In the present study, it was hypothesized that the impact of the distal risk factors were all mediated through proximal risk factors.

The purpose of this study was to examine the causal effects of distal (at year one of the study) and proximal (at year three of the study) risk factors for the use of so called *gateway* substances (see Kandel, & Faust, 1975) by Mexican American students identified with specific academically related difficulties and given the label *learning disabilities*. Given this, the present study was built on the following hypotheses:

1. Distal risk factors measured at year 1 (peer deviance, school satisfaction, self-esteem, language acculturation, and socialization acculturation) will directly influence the proximal risk factors (deviance, availability of substances, and a positive attitude toward substance use) measured at year 3.
2. Proximal risk factors will directly influence the use of substances at year 3.
3. Distal risk factors will indirectly influence the use of substances at year 3 via the mediating effects of the proximal risk factors.

Methods

Subjects and Procedures

Data for this study were collected in a school district in South Texas in which the majority of students enrolled are Mexican American (92 %). Students identified by school records as having either a verbal or nonverbal learning disability were surveyed in the district's four middle and two high schools. Students were identified by school officials as having a learning disability on the basis of the Texas State Board of Education Rules and Regulations, which are intended to comply with the Individuals With Disabilities Education Act (IDEA, PL 105-17), (US Department of Education Publications, 1997).

Sixty percent of the students in the district participate in the National School Lunch and Nutrition Program, and 69% overall are categorized as *at-risk* for academic failure according to Texas Education Agency standards. Family mobility of the students studied was relatively high with 35.3% of the families having relocated at least once in the past three years. Given the above characteristics, the subjects in the present study represent a group of Mexican American, low SES, high-risk adolescent students with learning disabilities.

Data were collected using a self-report questionnaire, which was administered in the spring of 1994 (year 1), 1996 (year 3) and 1997 (year 4). To control for standardized administration and readability, the survey was read aloud in English by trained university students with a maximum time allotment of 50 minutes. The students were directed to follow along with the survey administrator who read each question and multiple-choice answers aloud. Students did not appear to have difficulty understanding the survey questions. No school personnel were present during the administration. All students were paid one dollar for their participation at the end of the survey session.

Since the purpose of this study was to investigate the association of specific variables to the use of substances by students identified as having learning disabilities, the following was used to identify the subjects. In year 1 of the study, 275 students with learning disabilities in grades 7, 8, and 9 were identified based on information provided by the school district. In years 3 and 4, respectively, only 98 and 96 of the original 275 students with learning disabilities were surveyed. This low retention rate was mainly due to logistical difficulty to access students. However, there were no significant differences of substance use between the students who participated in later surveys and the students who did not.

In order to obtain a larger sample of students identified with learning disabilities, it was decided to perform data analysis on the substance use with information combined from year 3 and year 4 using year 3 as the time frame. For those students who did not participate in the year 3 survey, their information on substance use collected in year 4 was used instead. This decision was made based on the observation that the correlation of the use of substances was .78 between year 3 and year 4, whereas the correlation was .38 between year 1 and year 3 and .45 year 1 and year 4. The high correlation between years 3 and 4 suggests that the frequency of substance use became more consistent as children grew older. This is also consistent with previous findings where the use of substances in adolescents stabilizes over time, especially during the high school years (Johnston, O'Malley, & Bachman, 1999).

In summary, complete data were obtained from 136 students identified with learning disabilities from year 1 to year 3. The mean full-scale IQ of the students identified with learning disabilities was 88 (range 72-114; SD = 10.06). Sixty-six percent of the students with learning disabilities received resource room services as their administrative arrangement; 19% of the students were included all day in regular classes; and 15% were assigned to self-contained classrooms due to the severity of their learning disabilities. The mean age of the identified subjects with learning disabilities was 12.8 (SD = 1.34), and the range was from 11 to 15 years.

Exogenous/Predictor Variables

School Satisfaction. This was a scale with four items that measured students' satisfaction or dissatisfaction with their present schooling. Students were asked to indicate how they perceived (*felt about*) about their school. A sample item is: *I am satisfied with my school*. Responses include *never, sometimes* and *most of the time*. A high score means a higher level of satisfaction with school. The internal reliability coefficient for the scale was .74. School satisfaction was selected because it is believed that students (such as those identified as having learning disabilities) who do not perform well in one or more school subjects might are less inclined to report overall satisfaction with their educational environment than those perfo9rming well within that environment (Keilitz & Dunivant, 1986). Grande (1988) found that degree of satisfaction with one's school is linked to school failure and subsequent delinquency and substance use.

Self-esteem. This scale was adopted from Rosenberg's (1965) self-esteem measure with 10 items that have an internal reliability coefficient of .84. A high score on the scale indicates a higher level of self-esteem. Self-esteem is viewed by some researchers as an important personality construct defined as a confidence in and internal satisfaction with oneself. Researchers have found associations between low levels of measured self-esteem in adolescents and deviant behaviors, including substance use. Students identified with learning disabilities are theorized to be particularly prone to having low self-esteem based on a number of factors, including poor school performance (Grande, 1988).

Peer Deviance/Delinquency. This 9 item scale was developed to measure close friends' involvement in deviant acts such as school discipline problems, the use of substances such as cigarettes, alcohol, and marijuana, and other delinquent/anti-social acts. A sample question is, *How many of your close friends that you hang around with carry weapons like a knife or a gun?* Response categories were *none, some of them and most of them*. A higher score indicates a higher incidence of peer deviance. The internal reliability for this scale was .89. Based on differential association theory, researchers have known for some time that adolescents who associate with peers who engage in deviant behaviors also engage in these behaviors (Akers, 1992, Burgess & Akers, 1966). The old adage, *birds of a feather flock together* may have some validity for students with learning disabilities who might feel alienated by the conventional school structure and choose to associate with other less conventional peer groups (Akers, 1992). In fact, Keilitz and Dunivant (1986) posit that suggestibility and conformity may directly contribute to certain inappropriate behaviors by students with learning and behavioral disorders, including substance use.

Acculturation. Acculturation, defined as the process by which individuals change their behavior and attitudes toward those of the host society, is an important psychosocial concept (Rogler, Cortes, & Malgady, 1991). This 12 item scale used an existing valid and reliable instrument (Barona & Miller, 1994), which measures the acculturation behavior in areas such as the use of language (Spanish vs. English, 9 items pertaining to the language in which students watch TV, listen to the radio, and speak) and social activities related to the dominant Americanized culture (3 items related to the ethnicity and race of close friends, people with whom socialized and attend social gatherings). The internal reliability coefficients were .88 and .80 for the language use and social activity subscales, respectively. The internal reliability _ for the scale itself was .85. A higher score on either of these scales is indicative of more acceptance of the norms and values of American culture (e.g., predominantly speaking English and participating in Americanized activities). Both language acculturation and socialization acculturation were designed to measure levels of acculturation into the American. dominant culture by Mexican American adolescents. An important theory connecting substance use and involvement in deviant behaviors by Mexican American youth include the cultural-change, or stress theory explored by a number of researchers (Barrett, Joe, & Simpson, 1991; Vega, Alderete, Kolody, & Aguilar-Gaxiola, 1998; Vega & Gil, 1999).

Student Characteristics. Student gender, grade level at year 1, status in National Lunch Program and family mobility (number of times family has moved in the past three years) were included to adjust for confounding effects on student attrition. This information was obtained from the school district. These variables were included in the model as co-variates to control potential confounding effects.

Endogenous/Dependent Variables

Use of Substances. Students were asked the frequency of their use of cigarettes, beer, liquor, and marijuana in the past year. The categories of frequency of use were *never heard of it, never used it in the last year, 1 to 2 times, 3 to 10 times, 11 to 19 times, and 20+ times*. These categories are similar to other surveys of this type (TCADA, 1994). Previous studies have found the use of cigarettes, beer, liquor, and marijuana tends to cluster together while the use of other *harder* drugs (such as heroin, cocaine, and crack) also forms a distinct class (Zapata & Katims, 1993). The *gateway* substances will be hereafter referred to as simply substances and measured by summation of the self-reported frequency of use in the past year across the four years. Researchers have theorized that these *minor* substances act as *gateways, stepping stones*, or *avenues* to the subsequent use of harder substances such as cocaine, heroin, and hallucinogens (see Kandel, & Faust, 1975 for a complete description of this theory).

Availability of Substances. Students were asked to report if they were offered *gateway* substances in their neighborhood and in school. The responses were scored 0 for *no* and 1 for *yes*. After summing the responses, a high score indicates increased availability of substances to students.

Deviance/Delinquency. Students were assessed on their participation in deviant, anti-social, or delinquent activities and behaviors. A self-reported *yes* was assigned a score of 1 and a *no* a score of 0. Initial factor analysis revealed four factors with eigan values greater than 1. Examination of these factors found the first was pertaining to criminal acts (property theft, damaging private property, and carrying weapons) and the rest were delinquent acts (discipline problems at school, using bad language toward adults, and leaving home at night without parental permission). The final factor analysis restrained the factor solution to two factors and supported a two-factor construct with all factor loadings greater than .40. The Cronbach's α was .85 and .83 for criminal act subscale (9 items) and delinquent act subscale (11 items), respectively. The internal reliability coefficient for the total scale was .89. This index was included in the study because of the established link between school difficulties (a hallmark of a learning disability) and delinquency (Doll, 1921), including substance use (Keilitz & Dunivant, 1986) among school age youth.

Attitude Toward Substance Use. Students responded to a series of questions about their attitude toward and perception of the use of cigarettes, alcohol and marijuana, separately on a 5-point Likert scale. For example, students were asked *I think smoking cigarettes (drinking alcohol, smoking marijuana) is very uncool (1) to very cool (5). I think smoking cigarettes is bad for you.* The internal reliability coefficients were .89 for the scale. This scale was included because of the association between favorable attitudes toward substance use and the actual use of such substances established in the research literature (Johnston, et al., 1995).

Data Analysis

Structural equation modeling (SEM) was applied to test the hypothesized causal model, which measures the degree to which the model is congruent with the data. Because of the small sample size, a sub-model for path analysis with observed variables was used to perform this test instead of the latent variable approach (Joregkog & Sorbom, 1989). All the observed variables included in the model had high levels of reliability (with an internal reliability coefficient greater than .70; Pedhazur, 1982). The parameters were estimated with the Maximum Likelihood (ML) estimation method using the LISREL program (Joreskog & Sorbom, 1989).

Assessment of model fit was conducted by examining various indices of the overall individual parameter fits for the hypothesized model as suggested by Bollen (1989), Joregkog and Sorbom (1989) and Kelloway (1998). Chi-square (χ^2) statistics test the absolute fit of the hypothesized model with the population covariance matrix. It is well known that this index is too sensitive to sample size and data distribution (Joreskog & Sorbom, 1989). In this study, the following indices will also be used in combination to assess model fit. The Goodness of Fit Index (GFI) is based on a ratio of the sum of the squared discrepancies between the observed and population variance. The Adjusted Goodness of Fit Index (AGFI) adjusts the GFI for degree of freedom in the hypothesized model. A discrepancy between GFI and AGFI usually suggests that trivial or non-significant parameters are specified in the model. The Normed Fit Index (NFI) and Non-normed Fit Index (NNFI) indicate the amount of improvement in fit over a baseline independent model with the NNFI being adjusted to the number of degrees of freedom in the model. The Comparative Fit Index (CFI) was also proposed by Bentler (1990) to assess the improvement in fit of the hypothesized model compared to a complete independent model. These indices range from 0 to 1, with values above .90 indicating a good fit of the data. The Root Mean Square Error of Approximation (RMSEA) indicates the amount of unfitted residuals between the implied and observed covariance matrices. Values less than .10 are interpreted as a reasonable fit whereas values below .05 indicate very good fit of the data (Steiger, 1990).

In addition, t value associated with each estimate of the observed variable was used to assess whether it was adequately measured. A t value was calculated by dividing its unstandardized estimate by its standard error. A value greater than 1.96 indicates the parameter was significantly different from zero and therefore its dimensionality was correctly specified and fitted the data.

Finally, modification index can also be used to evaluate the model fit. It represents the decrease in model χ^2 that could be otherwise gained, if a parameter is allowed to be estimated. Only a modification index (MI) over 5.00 is deemed important enough to be considered. However, any model modification based on MI needs to be cautious and justifiable theoretically (Kelloway, 1998).

Results

Table 1 displays the correlation, mean and standard deviation of all variables included in the model. The result of the path analysis for the hypothesized model is depicted

Table 1

Correlation coefficients, means and standard deviations for measures used in path analysis

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	Mean	SD
1. Gender		.10	-.09	.12	-.04	.02	-.30[c]	-.09	-.15	.14	-.14	-.08	-.20[a]	N/A*	N/A*
2. Lunch			.10	-.08	.18[a]	-.11	-.12	-.20[a]	-.03	.02	-.07	-.03	.07	N/A*	N/A*
3. Number of moves in 1995				-.09	.16	-.14	-.19[a]	-.05	.04	-.01	-.05	-.08	.04	N/A*	N/A*
4. Grade attended in 1995					.02	.26[b]	.15	.02	-.19[a]	.08	-.06	.09	-.01	N/A*	N/A*
5. Peer deviance						-.19[a]	-.30[c]	.08	.07	-.25[b]	.24[b]	.37[c]	.36[c]	16.17	4.92
6. School satisfaction							.20[a]	.04	-.05	.09	-.19[a]	.002	-.06	7.93	2.18
7. Self-esteem total score								.07	.02	.03	-.06	.01	.02	27.74	4.86
8. Acculturation language									.29[c]	-.02	.15	.10	.11	40.42	8.57
9. Acculturation social										-.23[b]	.14	.13	.12	7.02	3.20
10. Attitude toward substance use											-.33	-.32[c]	-.45[c]	9.99	7.21
11. Deviance												.60[c]	.56[c]	5.12	5.02
12. substance availability													.62[c]	3.70	2.87
13. Use of substances														5.59	5.32

[a] Correlation is significant at the 0.05 level (2-tailed).

[b] Correlation is significant at the 0.01 level (2-tailed).

[c] Correlation is significant at the 0.001 level (2-tailed).

* Measured as categorical variable.

in Table 2 (as Model 1). With the exception of GFI (.91), all other indices showed the model fit the data inadequately. Examination of the modification index suggests that the variances of deviance and substance availability were highly correlated (MI = 38.90). Given the nature of these two variables (i.e., deviant children also have increased access to substances, or substances are more readily available among deviant children), their correlation is understandable. As a result, it can induce noise into the model and mask the hypothesized relationships (Bollen, 1989). Therefore, the original model was respecified by relaxing the restriction of independence between deviance and substance availability. This was accomplished by allowing the error co-variance between them to be freely estimated.

The result of the respecified model (Model 2, Table 2) indicated a significant improvement of fit. Specifically, GFI, CFI and NFI were all above .90 suggesting a good overall model fit and RMSEA was .05 indicating acceptable unfit residuals between the implied and observed co-variance matrices. Assessment of individual parameter fit found that all estimates had t values greater than 1.96 suggesting each parameter was adequately assessed. The path diagram of the respecified causal model with its respective path coefficients is depicted in Figure 1. Effects of the exogenous variables on self-reported deviance, availability of substances, and positive attitudes toward substance use are shown in Table 3.

Several important findings emerged. First, having peers that participate in deviance/delinquency and participating in more Americanized (or rather, Anglicized) activities through socialization acculturation had a significant direct effect on students reporting positive attitudes toward the use of substances. Also, peer deviance and lack of school satisfaction directly influenced self-reported deviance, whereas, self-esteem and language acculturation (speaking more English

Table 2

Comparison of Indices of Fit for the Two Proposed Models

	χ^2	df	GFI	AGFI	RMSEA	NFI	NNFI	CFI
Model 1	86.63	24	.92	.69	.14[1]	.72	.14	.73
Model 2	29.65	23	.97	.87	.052[2]	.90	.88	.97

Note. χ^2 = Chi-Square; df = Degrees of Freedom; GFI = Goodness of Fit Index; AGFI = Adjusted Goodness of Fit Index; RMSEA = Root Mean Square Error of Approximation; NFI = Normed Fit Index; NNFI = Non-Normed Fit Index; CFI = Comparative Fit Index. [1]90% CI (.10; .17) [2]90% CI (.00; .093)

Table 3

Total and indirect effects (standardized coefficient/standard error/t-value) of exogenous variables on endogenous variables

	Gender Status	Lunch	# of times moved	Grade	Peer deviance	School satisfaction	Self-esteem	Language acculturation	Socialization acculturation
Total effect on									
Positive attitude toward	--	--	--	--	0.32	-0.07	--	0.00	0.46
use of substances					(0.13)	(0.29)		(0.07)	(0.02)
					2.49	-0.25		-0.03	2.32
Deviance	-0.08	--	--	--	0.20	-0.43	-0.05	--	--
	(0.35)				(0.09)	(0.16)	(0.08)		
	-0.23				2.16	-2.60	-.063		
Availability of	--	--	--	--	0.21	--	-0.01	-0.01	0.04
substances					(0.05)		-0.61	-0.30	0.65
					4.41		-0.61	-0.30	0.65
Use of substances	-0.08	0.12	0.07	-0.01	0.28	-0.10	-0.01	-0.01	0.17
	(0.33)	(0.32)	(0.32)	(0.31)	(0.07)	(0.10)	(0.01)	(0.03)	(0.08)
	-0.25	0.39	0.23	-0.04	4.36	-0.98	-0.61	-0.20	2.18
Indirect effect on									
Use of substances	-0.01	--	--	--	0.28	-0.10	-0.10	-0.10	.17
	(0.06)				(0.07)	(0.10)	(0.01)	(0.03)	(0.08)
	-0.23				4.36	-0.98	-0.61	-0.20	2.18

than Spanish) did not. The distal risk factors of peer deviance and socialization acculturation had an effect on the use of substances by the subjects at year three. This was mediated, or indirectly related in year three by the proximal risk factors of self-reported deviance, availability of substances at school and in the neighborhood and a positive attitude toward substance use.

The use of substances by the subjects in year three was significantly predicted by self-reported deviance, substance availability at school and/or in the neighborhood, and positive attitudes toward substance use (proximal risk factors). As indicated by the decomposition of total effects, there was a significant indirect effect on substance use in year three by distal factors mediated by substance availability, deviance, and positive attitude toward substance use in year three. Specifically, significant indirect effects on the use of substances by proximal risk factors were peer deviance and socialization acculturation.

Discussion

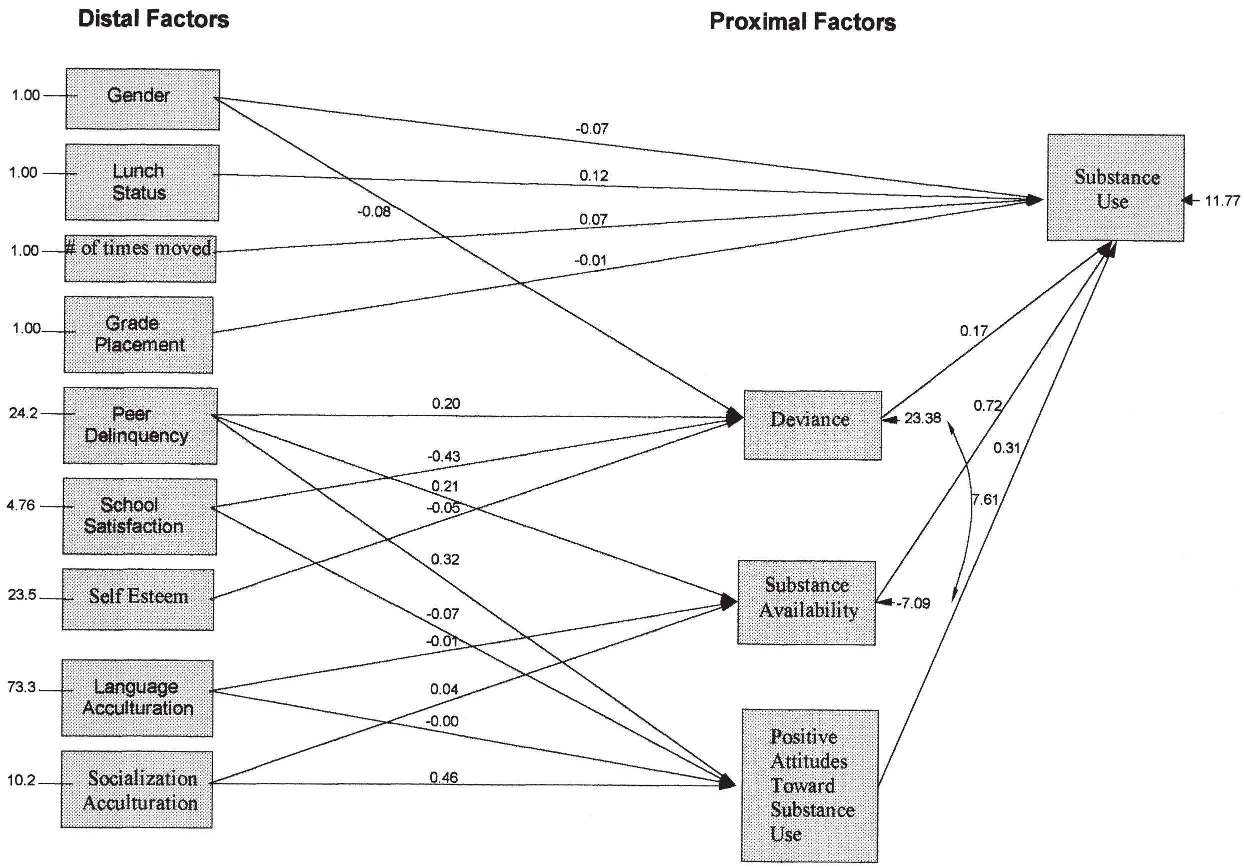
It appears that peer deviance and socialization acculturation (participating in Americanized/Anglicized activities) at year one predicts the use of substances at year three for this sample of Mexican American adolescents with learning disabilities. These distal risk factors were mediated by the proximal risk factors of self-reported deviance and a positive attitude toward substance use. These findings provided general support for the distal-proximal theory of the risk factors for substance use in this study sample.

Students who associated with deviant peers in year one were more likely to report relatively high levels of deviance/delinquency in year three of the study. It seems as though self-reported delinquency in year three operated as a mediator of substance use in year three. Differential association theory (Akers, 1992; Burgess & Akers, 1966) posits that deviant behavior, specifically substance use and deviancy/delinquency, are learned within intimate groups through the communication of both techniques and motivation for specific behaviors. Interactions with peers and others expose children to social environments that influence attitudes toward substance use and other delinquent acts and provide models and differential reinforcement of such behaviors. In fact, Akers (1992) found that their differential association with peers who use or do not use substances could best predict the use of substances by adolescents. The peer group with which the individual is involved, and how this peer group perceives the legal code will determine to a significant degree whether an adolescent will become involved in delinquent acts.

Peer delinquency affecting self-reported delinquent behavior is consistent with a study by Joe, Barrett, Simpson

Figure 1

Path Diagram of the Revised Causal Model



(1991) which found a strong relationship between Mexican American adolescents' association with deviant peers and self-reported levels of delinquent behavior and substance use. McBride, Joe, and Simpson (1991) also demonstrated that peer deviancy had a positive relationship with self-reported deviant behavior and criminal involvement.

Adolescents with learning disabilities may be grouped with other students who have poor academic achievement (whether in inclusive classrooms or not) and are viewed by peers who do not have learning disabilities and adults as problem students. Such negative labeling and association with other problem students may prompt youth with learning disabilities to engage in socially troublesome behavior to satisfy an increased need for recognition and achievement in a delinquent-prone peer group. Deshler and Schumaker (1983) found that adolescents with learning disabilities are less socially assured and more prone to conform to group values to gain social acceptance than are adolescents without learning disabilities. In a cross-sectional study Katims, Zapata, and Yin (1996) found that Mexican American students with learning disabilities, as opposed to a matched sample without learning disabilities were at risk for substance use by having close friends who used substances and by their self-reported susceptibility to peer influence. Two other studies with adolescent students with learning disabilities found these students indicated a greater willingness than students without disabilities to accede to friends' wishes that they join in with their friends in misconduct (Bryan, Pearl, & Fallon, 1989; Bryan, Werner, & Pearl, 1982). Overall, findings from the current study clearly suggest that peer delinquency in year one leads to positive attitudes toward substance use and availability of substances, with actual substance use in year three. This is apparently due to peer group influence.

Socialization acculturation, or engaging with non-Hispanic peers in social activities related to the dominant Americanized culture in year one was related to positive attitudes about substance use and actual substance use in year three. This notion that association with, and participation in, Americanized activities increases the risk for substance use is a phenomenon described by other researchers (Matsueda & Heimer, 1987; Oetting & Beauvais, 1986; Vega & Gil, 1999). As the level of acculturation increases, adolescents tended to spend more time with peers and school-related activities (Reuschenberg & Buriel, 1989). Consequently, increased time spent in the systems outside of the family can lead Mexican American youth to increased association with deviant peers and peer-related stressors and more tolerance of deviancy and willingness to defy authority (Wall, Power, & Arbona, 1993). Vega and Gil (1999) further contend that the socialization experiences of the Hispanic adolescent with white, middle class peers exerts a strong influence on traditional Mexican American cultural, family, and community values. This influence in turn presents a substantive risk factor for attitudes and behaviors related to substance use.

It is also theorized that stress and conflict between the traditional values of parents and adolescents might play a role in the adolescent's substance use. It appears that this influence might be particularly strong for students with learning disabilities. However, there is no direct evidence in this study or in most others on this topic supporting the concept that stress or conflicts exists between the traditional values of parents and adolescents. It is more likely that interaction with, and exposure to, white middle class culture in this particular case brings students into contact with other students who engage in deviant behaviors, including substance use, and that this contact facilitates their own substance use. As added support for this position, it appears that language acculturation is not related to substance use. This finding suggests that the psychological movement toward English or even bilingualism is not sufficient to result in increased substance use. What is required is more active involvement and interaction with the white middle class culture.

The findings of this longitudinal study seem to indicate that for Mexican American adolescents identified with learning disabilities, peer delinquency and socialization acculturation are powerful risk factors for substance use. As Vega and co-workers (1993) found, accelerated risk for substance use is a consequence of the Americanization acculturation process on the healthy development of adolescents and early adulthood among Mexican Americans. Ebin and colleagues (Ebin, et al., 2001) also valiantly point out that to promote healthy lifestyles in Latino youth, intervention programs must take into account of the influence of acculturative process. In keeping with the 19th Annual Report to Congress on the Implementation of the IDEA (US Department of Education, 1997), school and public health officials would be wise to develop and implement intervention and prevention programs based on research that promotes resiliency against substance use among minority youth with learning disabilities.

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Book Review

Research and Global Perspectives in Learning Disabilities: Essays in Honor of William M. Cruickshank by D.P. Hallahan and B.K. Keogh (Eds.). Mahwah, New Jersey: Lawrence Erlbaum Associates, (2001)

Reviewed by Harold J. McGrady

Introduction

The field of learning disabilities is at a crossroads in the United States. Definitions and concepts are being challenged; legislation is influencing the identification and services being provided in the schools; and the nature of professional training programs is being questioned. Where should we look for answers? The editors of this book have selected an outstanding array of authors to look in three places: (1) the history and foundational concepts of the field (the past); (2) research (the present); and (3) research and practice around the globe (the future?).

If we are to understand the present, perhaps we should look to the past and review the genesis of the learning disabilities concept. Such a search might lead us *back to the future* as we seek solutions to current problems and guidance for future direction. This book meets those goals. It is a *festschrift*, a volume of writings by different authors presented as a tribute to the lifetime contributions of an American pioneer in learning disabilities, Dr. William M. Cruickshank.

Content and Organization of the Book

Editors Daniel Hallahan and Barbara Keogh present a cogent abbreviated version of the history of learning disabilities and issues related to definition, together with a discussion of current challenges and realities for the field. Next, a chapter by Doris Johnson and Barbara Keogh recounts the lives and careers of Bill and Dorothy Cruickshank. Subsequent chapters confirm the solid and lasting foundation of Cruickshank's writings and thoughts about learning disabilities. The contributed essays, written by distinguished writers and researchers, consistently validate Cruickshank's primary concepts. Many of the authors relate their current research findings directly to concepts and precepts promulgated by Dr. Cruickshank. As the editors state, the book is organized *thematically around the major ideas that Bill Cruickshank espoused over his career*. (p.8)

In testimony to Cruickshank's vision, there are chapters on the neurobiological basis of learning disabilities, the co-morbid condition of ADHD, social functioning of students with learning disabilities, assessment, strategic learning, structure and effective teaching, the concept of least restrictive environment (LRE), and learning disabilities as a problem over the life span. The book also exposes research perspectives and practices in learning disabilities from various parts of the world: Australia, Canada, Germany, Britain, Japan, the Netherlands, Scandinavia, and South America. In a concluding chapter, Susan Vogel discusses the challenge of international research in learning disabilities, a development that would be very gratifying to Cruickshank.

This book will be very useful as a resource for graduate students and others in education, especially to gain an understanding of key principles and prominent research efforts in learning disabilities. A sample of what may be found in this text follows.

Highlights from Research in the United States

Modern technological advances are gradually providing confirmation of many early hypotheses about the underlying causes of learning disabilities. For those who are skeptical about the neurological basis of learning disabilities, the latest substantiating evidence is reported in the chapter by Michelle Kibby and George Hynd.

Two chapters focus on specific characteristics associated with learning disabilities. Ronald Kotkin, Steven Forness, and Kenneth Kavale discuss the diagnosis, special education, and intervention for attention deficit hyperactivity disorder (ADHD) as a co-morbid condition with learning disabilities. Deepa Sridhar and Sharon Vaughn present a comprehensive chapter about research into the social functioning of persons with learning disabilities. They provide two comprehensive charts summarizing findings from interventions into the social functioning of students with learning disabilities. One chart summarizes research from peer-mediated interventions; the other considers findings and effects of adult-mediated interventions.

Lynn and Douglas Fuchs report their research and conclusions about two topics of current concern: (1) accommodations for testing, and (2) the use of supplementary assessment and accountability systems for students with learning disabilities, particularly curriculum-based measurement (CBM). These concerns have been generated by increasing demands for accountability in the schools. The Fuchs' presentation makes a strong case for the use of CBM, but pleads for more research on the subject of standardizing accommodations for students with learning disabilities who are subjected to high stakes testing.

Paul Gerber addresses the life span approach for learning disabilities and discusses various issues related to the long term fate of persons with learning disabilities.

Two chapters address specific approaches to intervention: one on strategic learning, by Lynn Meltzer and Marjorie Montague; the other on structure and effective teaching, by Margaret Weiss and John Lloyd. Both chapters give the reader an understanding of basic tenets of instruction for students with learning disabilities. Meltzer and Montague have stated the basic premise for emphasis on intervention, particularly strategic learning:

> *Over the past 40 years, conceptualizations of learning disabilities have changed from unitary approaches that emphasize isolated processes toward multidimensional approaches that focus on the interactions between neurologically based characteristics and environmentally transmitted influences. . . . There is a growing understanding that learning problems are influenced by the complexity of the curriculum and the style of teaching.* (p. 111)

Meltzer and Montague present a comprehensive understanding of strategic learning and its implications for students with learning disabilties. Of particular interest is their discussion of the implications for use of strategic learning in inclusive classrooms. They conclude that: *research-based strategy instruction needs to be provided by expert remedial teachers who understand the characteristics of students with learning disabilities and the principles associated with assisting students in learning, applying, and generalizing strategies.* (pp. 123-124)

Weiss and Lloyd provide additional support for individualized intensive instruction in their chapter, which might be considered a primer on use of structure in the classroom, a favored construct for Cruickshank.

In perhaps one of the most erudite chapters in this volume, Crockett and Kauffman have examined the concept of least restrictive environment (LRE) and its implications for students with learning disabilities. They discuss the controversies surrounding this particular service delivery and relate these issues to legal and special education principles. Perhaps the best way to summarize these authors' conclusions about LRE, is to repeat a quote which they cite directly from an editorial written by Cruickshank in 1977:

> *A child placed in a so-called least restrictive situation who is unable to achieve, who lacks an understanding teacher, who does not have appropriate learning materials, who is faced with tasks he cannot manage, whose failure results in negative comments by his classmates, and whose parents reflect frustration to him when he is at home, is indeed being restricted on all sides.* (Cruickshank, 1977, p. 193)

Again, quoting from Cruickshank (1967), they note that: *special education exists because some children present problems which cannot be readily solved by general education* (p. 21). Crockett and Kauffman further support their call for specialized instruction by quoting another prominent researcher, Naomi Zigmond, . . . *special education is, first and foremost, instruction focused on individual need. It is carefully planned. It is intensive, urgent, relentless, and goal directed. It is empirically supported practice, drawn from research. To provide special education means to set priorities and select carefully what needs to be taught. It means teaching something special and teaching it in a special way* (Zigmond, 1997, pp. 384-385).

Global Perspectives

Perhaps the most unique and mind-expanding aspect of this volume is the inclusion of essays from researchers in various parts of the world. Nations around the globe are struggling to discover how best to educate failing learners in a technologically more complex world, a universe which demands increasingly higher levels of skill in literacy and numeracy. These authors make it clear that a diversity of cultures, varying societal organizations, unique political systems, and other environmental aspects have created a range of alternatives for the education of children and adults with learning disabilities.

There is a contrast in the emphasis placed on learning disabilities in the more developed countries, such as the European countries, and the developing regions, such as South America. It is interesting to note that there is no chapter representing any country on the continent of Africa. Learning disabilities might be considered a somewhat sophisticated educational category, being of greater significance as a specific entity in those more highly developed parts of the world where high degrees of literacy are demanded for success in life. In other countries the emphasis in education is primarily to increase the literacy rates for the general populations and to increase the underlying socioeconomic base for the populace. Development of learning disability programs in South America, for example, have shown a gradual evolution typical to, and influenced by, the United States history in this field. On that continent, concern for learning disabilities first arose in medical clinics and was stimulated by the works of Strauss, Cruickshank, and Myklebust from the United States. But attempts to operationalize the concept in the schools are confounded by the overwhelming numbers of children living in low socioeconomic (SES) circumstances. As in some other regions of the world, intervention for students with learning disabilities is considered primarily a part of general education responsibility.

The research in South America, together with that in European and Asian countries where English is not the primary language, provide immense possibilities for cross comparisons of reading disabilities found among the various languages. Often writers in non-English speaking countries refer to their language as being more *transparent* phonologically than English. This factor should provide an excellent opportunity for comparative research to improve our understanding of the process of learning to read.

American readers may be proud that many American approaches to the education of persons with disabilities have spread across the globe. However, it is sobering to reflect that, in contrast to most other regions in the world community, the United States approach is far more litigious and political. As this reviewer noted in 1979 at the University of Queensland, Australia:

> *We could accomplish . . . well designed comprehensive research studies and . . . arrive at deliberated conclusions as to how we should handle (various problems of special education) . . . But in America that is not the way we do it. We legislate and we litigate. Legislation and litigation are the cornerstones of the current methods for operation and delivery of services for special education children in the US today . . . It's the American way."*
> (McGrady, 1979)

There is much to learn by examining approaches taken in other countries. For example, the definition of leaarning disabilities varies throughout the world. Although a few countries have adopted theAmerican definition or something very similar (e.g., Canada and Japan), many no longer tie their programs to the American model. Some, such as Australia and Britain, have opted for the term *learning differences* and others, such as The Netherlands and Scandinavia, prefer to consider the various specific disabilities singularly (e.g., dyslexia), not using the heterogeneous construct adopted in the United States. (National Joint Committee on Learning Disabilities, 2001) The German system appears to consider a broader definition for learning disabilities, including students that would be called slow *learners* or *borderline* in the United States.

Stevens and Werkhoven, in the Netherlands, express a general dissatisfaction with the approach of differential diagnosis. The expectation was that such an approach would lead to appropriate treatment, but they conclude, this was never *fully realized* (p.273). Consequently, the Netherlands considers learning disabilities as part of a more general concept: *learning and behavioral problems*.

Most countries have stressed reading disorders as the prime condition of concern. But, nearly all countries have come to understand that there is a difference between learning *disabilities* and learning *problems*. Opp, in Germany, for example, best described this. He compares the *syndrome* of learning disabilities, which has an assumed neuropsychological basis, with a larger population of students whose learning failures are associated with socio-cultural disadvantages.

Service delivery systems are strongly influenced by socio-political factors:

1. The culture, as with the historical base of a class strata and segregated schools for children with disabilities in Germany, or the preponderance of low SES students in the schools of South America;
2. The political system, e.g., the contrast between democratic and socialistic countries;
3. exposure to American concepts through translated works or presentations made by American pioneers in the field, such as Bill Cruickshank, Sam Kirk, and Helmer Myklebust; or
4. Societal pressures, such as the strong parent movements in Canada, Britain, and Japan.

The interdependence of these factors was best stated by Stevens and Werkhoven in the Netherlands: *As long as the expertise in educational practice cannot formulate an adequate answer with respect to the educational needs of pupils, the government will try to control the flow of pupils using financial measures* (p.287).

Some writers addressed the controversial issue of inclusion. Opp contrasted the advantages and disadvantages of *integration*, reporting that results of research in Germany are somewhat contradictory. He concluded that educational effects are dependent on how much heterogeneity individual teachers or educational teams can handle and how many additional resources would be needed or provided in specific situations.

Perhaps the most significant world-wide trend is for increased attention to teaching, whether remedial or special, rather than diagnosis per se. For example, the Netherlands authors state:

> *One of the most important developments in the 1980s and 1990s was the reduction in interest in the behavioral characteristics of children with learning difficulties in favor of a growing interest in teaching and instruction processes and in the strategies used while learning to read, to spell, and to do arithmetic* (p. 278).

This shift has influenced the types of research being conducted in that country, particularly in the area of reading disabilities. It has also led to an increasing emphasis on *prevention* of reading difficulties and a gradual demise in the use of discrepancy data and/or exclusionary criteria.

Some nations continue to maintain special schools and/or classes for students with learning disabilities. However, an approach that is favored in several countries is an emphasis on improving instruction and curriculum for the general population of learners. The general goal is to enable all students to achieve literacy and numeracy. In addition, some countries provide support services, but, as Elkins states for Australia, *Professionals will reserve the term learning disabilities for a small group of students with severe problems who have not benefited from typical support programs* (p.188).

Concluding Remarks

The reader can gain much from the perspectives of various researchers from around the globe. The similarities and agreements across cultures are comforting and reinforcing, but the dissimilarities should give us pause to reflect on our own approaches in the United States.

As Elkins points out in his essay from Australia, there are many competing models for dealing with learning disabilities, *Yet it would be unwise to discard them, since each has a partial view of truth. These models (medical, psychological process, behavioral, and cognitive strategy) are each too narrow to be useful for all students* (p. 189).

The Australian approach is one to which the United States is beginning to migrate. Adoption of this approach is even more likely to occur with the advent of substantial support from the federal government to improve the reading and math competencies of students in the United States. In the Australian approach, a strong emphasis is placed on teaching literacy and numeracy in the general curriculum of the primary grades, accompanied by early identification of those students who struggle to achieve critical learning skills. A key to success under such a system appears to be the application of timely, appropriate, and intensive support services during all phases of the child's education, especially for those who are identified as having difficulty. Only those students who continue to be resistive to carefully planned instruction interventions are considered to have learning disabilities and receive additional, more intensive and individualized special education services.

Regardless of the system through which children receive their formal education, the secret to success for those with learning disabilities might have been best stated by Elkins, who concludes that the goal is to find the *correct fit between the needs of the pupils and the characteristics of the educational environment.* (p. 288) Dr. Cruickshank would probably agree.

Thanks to editors Daniel Hallahan and Barbara Keogh. They have demonstrated why they, too, are leaders in the field of learning disabilities. Through exposure to research and thinking from around the globe, they have made this reviewer think more deeply about how we might improve our system for educating children with learning disabilities in this country.

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DISABILITIES
A Multidisciplinary Journal

Janet W. Lerner
Editor-in-Chief

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Learning Disabilities: A Multidisciplinary Journal is an official publication of the Learning Disabilities Association of America (LDA). The journal is a vehicle for disseminating the most current thinking on learning disabilities and to provide information on research, practice, theory, issues, and trends regarding learning disabilities from the perspectives of varied disciplines involved in broadening the understanding of learning disabilities. The disciplines represented in the journal include adults, advocacy, assessment, college programs, cultural differences, early childhood, public and private education, families, higher and adult education, law, mental health, public policy, research, science, social and emotional issues, social work, technology, and vocational and career education.

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