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# Academic Underachievement Among Children With Epilepsy: Proportion Exceeding Psychometric Criteria for Learning Disability and Associated Risk Factors

**Philip S. Fastenau**,
Indiana University–Purdue University Indianapolis

**Jianzhao Shen**,
Indiana University School of Medicine

**David W. Dunn**, and
Indiana University School of Medicine

**Joan K. Austin**
Indiana University School of Nursing

## Abstract

This study assessed rates of learning disabilities (LD) by several psychometric definitions in children with epilepsy and identified risk factors. Participants (*N* = 173, ages 8–15 years) completed IQ screening, academic achievement testing, and structured interviews. Children with significant head injury, chronic physical conditions, or mental retardation were excluded. Using an IQ–achievement discrepancy definition, 48% exceeded the cutoff for LD in at least one academic area; using low-achievement definitions, 41% to 62% exceeded cutoffs in at least one academic area. Younger children with generalized nonabsence seizures were at increased risk for math LD using the IQ–achievement discrepancy definition; age of seizure onset and attention-deficit/hyperactivity disorder (ADHD) were risk factors for reading and math LD using low-achievement definitions. Writing was the most common domain affected, but neither ADHD nor seizure variables reliably identified children at risk for writing LD. Although children with earlier seizure onset, generalized nonabsence seizures, and comorbid ADHD appear to be at increased risk for some types of LD by some definitions, these findings largely suggest that all children with epilepsy should be considered vulnerable to LD. A diagnosis of epilepsy (even with controlled seizures and less severe seizure types) should provide sufficient cause to screen school-age children for LD and comorbid ADHD.

### Keywords

underachievement; epilepsy; IQ-acheivement discrepancies; writing; seizures assessment identification; attention-deficit/hyperactivity disorder (ADHD)

One percent of children will develop epilepsy by 20 years of age (Hauser, 1994). Children with epilepsy are at greater risk for academic difficulties compared to healthy children and compared to those with many other chronic illnesses of childhood (Austin, Huberty, Huster, & Dunn, 1998; Fowler, Johnson, & Atkinson, 1985; Westbrook, Silver, Coupey, & Shinnar, 1991). Furthermore, children with epilepsy are less successful than their peers without epilepsy at obtaining gainful employment as adults (Dodrill & Clemmons, 1984; Sillanpää, Jalava, Kaleva, & Shinnar, 1998). Although many studies have documented that children with epilepsy tend to have difficulties in school, it is unclear how many of these children would meet criteria for learning disabilities (LD) or for obtaining services.

## LD Screening

With the implementation of the Education for All Handicapped Children Act of 1975, the U.S. Office of Education provided an operational definition of LD that required a "severe discrepancy between achievement and intellectual ability in one or more … areas" of achievement (Assistance to States for Education of Handicapped Children: Procedures for Evaluating Specific Learning Disabilities, 1977). The stipulation of a severe discrepancy between achievement and IQ was retained in the Individuals with Disabilities Education Act (IDEA) amendments of 1997. The majority of state definitions have included a discrepancy criterion for many years (Frankenberger & Fronzaglio, 1991; Mercer, Jordan, Allsopp, & Mercer, 1996; Mercer, King-Sears, & Mercer, 1990), and 96% of states were continuing to use IQ–achievement discrepancy in their classification criteria as recently as 2002 (Reschly & Hosp, 2004). More than half of the states reported using standard scores, and 90% of those specified a discrepancy cutoff of 1 *SD* or greater (Frankenberger & Fronzaglio, 1991). Criticism of the role and utility of IQ in defining LD has led some to advocate for defining LD using a "low-achievement" criterion (i.e., comparison to the mean for achievement tests, without regard to IQ). These definitions have been compared and debated (e.g., Epps, Ysseldyke, & Algozzine, 1983; Kavale, 1995), but both definitions persist in the literature.

Both the IQ–achievement discrepancy and low-achievement approaches for individual classification have come under scrutiny. Fletcher and his colleagues have challenged the assumption that comparisons to IQ are valid indicators of underachievement and have highlighted the statistical limitations of psychometric cutoffs for individual classification (e.g., Fletcher, Coulter, Reschly, & Vaughn, 2004; Francis, Fletcher, Stuebing, Lyon, Shaywitz, & Shaywitz, 2005). Instead, they have advocated for serial testing (i.e., documenting change over time) or response to intervention (RTI) as being more empirically defensible for LD identification. These alternatives are unencumbered by the statistical limitations attributed to the use of IQ in defining LD, and RTI carries the additional advantage of promoting earlier intervention. Whereas Fletcher et al. (2004) criticized the use of IQ in LD classification and *extensive* assessment to identify LD, they nonetheless acknowledged a role for focused achievement testing even with an RTI approach, stating that "screening and evaluation of academic skills in the service of intervention and to determine level of risk for LD is not time consuming" (p. 309). Therefore, low achievement on a focused battery of academic measures can help identify children who are at risk and who need intervention.

Others continue to advocate for IQ–achievement discrepancy definitions for screening purposes. In a comprehensive review and analysis of the issues and empirical data addressing the use of discrepancy models in LD, Kavale (2002) argued that an IQ–achievement discrepancy is useful for screening for LD and can help to document underachievement, which is a necessary (although not sufficient) element in the definition of LD. Therefore, an initial assessment comparing actual achievement to the child's potential (i.e., IQ) is a defensible approach to *screening* for LD, especially for group-level research. For screening purposes, a liberal discrepancy (e.g., 1 *SD*) would be appropriate, especially given error of measurement issues (e.g., Francis et al., 2005).

With the reauthorization of IDEA in 2004 (Individuals with Disabilities Education Improvement Act of 2004), local educational agencies are no longer required to consider discrepancy from IQ and are allowed to use empirically validated processes of RTI as alternatives. This change provides more latitude to local agencies. It remains unclear, however, whether states will change their criteria, how quickly they will change, and which definition they will adopt.

## Limitations in Past Research on Children With Epilepsy

Past studies of achievement with children who have epilepsy had several limitations with regard to estimating the proportion of children with epilepsy who met a discrepancy criterion or low-achievement definition for LD. First, several studies focused on very specific subgroups of children with specific epilepsy syndromes (Camfield et al., 1984; Croona, Kihlgren, Lundberg, Eeg-Olofsson, & Eeg-Olofsson, 1999; Hermann, Seidenberg, Schoenfeld, & Davies, 1997; Schoenfeld et al., 1999; Williams et al., 1996), which might limit the generalizability of their findings to the broader population of school-age children with epilepsy. Second, many studies relied on very small groups of children with epilepsy (e.g., Aldenkamp, Overweg-Plandsoen, & Diepman, 1999; Camfield et al., 1984; Croona et al., 1999; Farwell, Dodrill, & Batzel, 1985; Pazzaglia & Frank-Pazzaglia, 1976; Stores & Hart, 1976; Sturniolo & Galletti, 1994; Westbrook et al., 1991).

Third, some studies defined academic underachievement by using data other than psychometric achievement tests. Outcome measures in those studies included grades repeated (Bailet & Turk, 2000; Pazzaglia & Frank-Pazzaglia, 1976; Schouten, Oostrom, Pestman, Peters, & Jennekens-Schinkel, 2002), placement in special education classrooms or schools (Bailet & Turk, 2000; Bulteau et al., 2000; Pazzaglia & Frank-Pazzaglia, 1976; Schouten et al., 2002; Zelnik, Sa'adi, Silman-Stolar, & Goikhman, 2001), teacher judgments (Holdsworth & Whitmore, 1974; Sturniolo & Galletti, 1994), teacher ratings (Croona et al., 1999; Huberty, Austin, Huster, & Dunn, 2000; Huberty, Austin, Risinger, & McNelis, 1992a, 1992b), and absence from school (Fowler et al., 1985; Westbrook et al., 1991). Even studies that used psychometric achievement tests, though informative for other research questions, did not lend themselves to the goal of defining the proportion of children with epilepsy who met current criteria for LD and low achievement. Several studies were based on *group* academic achievement tests (Austin et al., 1998; Fowler et al., 1985; Huberty et al., 1992a, 1992b; Tennison et al., 1998), and some of those applied parametric statistics to percentile ranks without converting them to normally distributed standardized scores (Fowler et al., 1985; Tennison et al., 1998). Studies using *individualized* achievement tests lacked critical information to inform the question at hand. Many studies examined achievement tests and IQ separately, without computing the difference between the two sets of scores (e.g., Aldenkamp et al., 1999; Seidenberg et al., 1986). Most studies sampled only a very few academic domains. Domains assessed were typically word decoding, spelling, and computational math (e.g., Aldenkamp et al., 1999; Austin et al., 1998), and much less frequently reading comprehension (Mitchell, Chavez, Lee, & Guzman, 1991; Seidenberg et al., 1986); very few studies assessed other fundamental domains such as math reasoning and writing composition, and no studies assessed all six domains in children with epilepsy.

Moreover, only two studies used an IQ–achievement discrepancy definition of underachievement (Mitchell et al., 1991; Seidenberg et al., 1986). Those that defined underachievement in this manner used cutoffs that were more liberal than those used by most state agencies: One study defined the discrepancy as 0.50 SD (Mitchell et al., 1991), and the other used a 0.80 *SD* discrepancy (Seidenberg et al., 1986).

Finally, past studies did not consider the potentially confounding role of attention-deficit/hyperactivity disorder (ADHD). Dunn, Austin, Harezlak, and Ambrosius (2003) found that 37.7% of children and adolescents with epilepsy (ages 9 through 14) met diagnostic criteria for ADHD on a structured interview. Furthermore, the majority of youth in that study exhibited the inattentive subtype, without prominent symptoms of hyperactivity or impulsivity. Therefore, children with epilepsy might be easily overlooked and undertreated for their attentional problems. A vast literature has documented the high comorbidity between ADHD and LD (Biederman et al., 1991), and rates of LD in the ADHD population have ranged from

17% using very conservative definitions of LD (Semrud-Clikeman et al., 1992) to 70% using more liberal criteria (Mayes et al., 2000). These robust relationships were evident using both IQ–achievement discrepancy definitions (Mayes et al., 2000) and low-achievement definitions (Willcutt & Pennington, 2000). Furthermore, the association with LD in reading was stronger for inattentive symptoms of ADHD than for symptoms of hyper-activity and impulsivity (Willcutt & Pennington, 2000). Given these comorbidities and the potential contributory role that attention problems might play in LD for children with epilepsy, it would seem important to model the effects of ADHD on academic achievement in this population. We are aware of no studies to date that have examined the relationship between ADHD and LD in children with epilepsy.

## Seizure Variables Related to Achievement

In addition to defining the rates of children who meet various definitions for LD, it would be beneficial to identify the seizure variables that might place children at greater risk for LD. Past studies examining the role of various seizure variables on academic achievement have met with mixed results. Inadequate *seizure control* has been associated with low achievement in some studies (Aldenkamp et al., 1999; Williams et al., 1996; Zelnik et al., 2001), as well as with intellectual decline (Rodin, Schmaltz, & Twitty, 1986), but this has not been uniformly reported (Schouten et al., 2002).

Early *age of onset* was associated with lower academic achievement in two studies (Schoenfeld et al., 1999; Zelnik et al., 2001), but most studies failed to find an association (Bailet & Turk, 2000; Hartlage & Green, 1972; Holdsworth & Whitmore, 1974; Huberty et al., 1992b; Mitchell et al., 1991; Sturniolo & Galletti, 1994; Williams et al., 1996). Similar (and highly related) to age of onset, a longer *duration of the disorder* has been associated with lower achievement in several studies (Farwell et al., 1985; Seidenberg et al., 1986; Seidenberg et al., 1988) but not in others (Mitchell et al., 1991; Sturniolo & Galletti, 1994).

*Medication* failed to show a relationship with academic achievement in some studies (Mitchell et al., 1991; Schoenfeld et al., 1999). However, one study with a specific epilepsy syndrome (Rolandic epilepsy) showed a trend for higher rates of comorbid LD, ADHD, and tics (36%) in children who required multiple antiepileptic medications (i.e., polytherapy) compared to comorbidity rates in children whose seizures were controlled with one or no medication (13%; Al-Twajri & Shevell, 2002). Hermann, Whitman, and Dell (1989) reported that academic achievement was lower for children on polytherapy versus monotherapy, but this was based on parent ratings of achievement, not standardized testing, and was observed only in boys. Also, high blood levels of one medication were associated with declines in general cognitive abilities in one study (e.g., Rodin et al., 1986).

*Seizure type and epileptic syndrome* have not been significantly related to achievement in most studies of children without mental retardation (Bailet & Turk, 2000; Hartlage & Green, 1972; Holdsworth & Whitmore, 1974; Huberty et al., 1992b; Mitchell et al., 1991; Sturniolo & Galletti, 1994; Williams et al., 1996). However, all three studies that have observed relationships with epileptic syndrome reported higher rates of learning problems in children with partial epilepsy (which is most often of symptomatic etiology) compared to generalized epilepsy (Stores & Hart, 1976) and in lesional/symptomatic syndromes compared to idiopathic or cryptogenic syndromes (Sillanpää, 2004; Zelnik et al., 2001). Other variables have failed to show strong relationships with academic achievement, including *seizure frequency* (Bailet & Turk, 2000; Hartlage & Green, 1972; Holdsworth & Whitmore, 1974; Huberty et al., 1992b; Mitchell et al., 1991; Schoenfeld et al., 1999) and *hemisphere of seizure focus* (Camfield et al., 1984; Schoenfeld et al., 1999).

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*Seizure severity* has been measured using a few different combinations of ratings of other seizure variables. These indices have met with mixed findings in the study of academic achievement. Huberty et al. (2000) created a seizure severity index that integrated seizure type, seizure frequency, and medication status; decline in group achievement test scores was associated with high severity, as classified by that index. Using a similar index (which included duration), Mitchell et al. (1991) found no relationship with scores on individual achievement tests, before or after adjusting achievement scores for IQ. Thus, the role of seizure variables in achievement remains unclear, but seizure control, age of onset/duration, seizure type/ syndrome, and polytherapy appear to warrant further investigation.

## Present Study and Hypotheses

The present study builds on past studies by (a) using a more comprehensive battery of academic achievement, (b) defining underachievement using several prevailing definitions (IQ–achievement discrepancy and low achievement), (c) using a relatively large sample of children with diverse seizure types, (d) examining the seizure factors that might place children at risk for being classified with LD, and (e) examining the role of ADHD in LD in this population. It was hypothesized that children with epilepsy would meet LD criteria by all definitions with greater frequency than is observed in the general population. It was further hypothesized that higher rates of LD would be associated with the following risk factors: (a) active seizures, (b) generalized seizure types (except for absence epilepsy), (c) polytherapy (i.e., taking multiple antiepileptic medications to control the seizures), (d) earlier age of onset of the seizure condition, and (e) presence of ADHD.

## Method

### Sample

Participants were recruited from outpatient pediatric neurology clinics, private pediatric neurology practices, and school nurses in Indiana and neighboring areas. Letters, brochures, and flyers were sent to nurses at all schools on a mailing list that was provided by the state of Indiana. Furthermore, all child neurology clinics in the greater Indianapolis area were contacted and were provided with letters, brochures, and flyers describing the study. The sample size was determined based on power analyses conducted prior to the initiation of the study. Of the 173 children who participated, 164 completed academic achievement testing. Age ranged from 8 to 15 years. Each child entered the study with a diagnosis of epilepsy; all children were on antiepileptic medications at the time of enrollment (although a few children discontinued medication between the time of enrollment and the time of neuropsychological evaluation). Children were excluded if they had a history of any of the following prior to enrollment into the study: traumatic brain injury resulting in loss of consciousness exceeding 30 min, skull fracture, or any permanent cognitive–behavioral changes; other chronic physical conditions (e.g., diabetes, asthma, cystic fibrosis); or mental retardation (based on formal diagnosis or by a corresponding classification in the schools, either of which presumes a measured IQ in the mental deficiency range on a full IQ test). Demographic and clinical characteristics of the sample are presented in Table 1.

### Procedure

An institutional review board approved the study; legal guardians of all participants signed informed consent statements prior to participation, and the children gave informed assent. Parents completed an extensive structured interview by phone with a carefully trained nurse or clinical research assistant; demographic data and seizure history (including age of onset, medication status, and degree of seizure control) were obtained as part of that interview. The children completed a structured interview by phone and completed a comprehensive neuropsychological evaluation at the medical center. A board-certified child neurologist reviewed electroencephalograms, neuroimaging reports (magnetic resonance imaging or computerized tomography), and clinic notes to classify each child's seizure types for the study.

Trained psychometrists conducted neuropsychological testing with each child individually. All tests in the neuropsychological battery (including the IQ screening and achievement tests) were administered in the same order for all children in the study. We are not aware of any study documenting order effects with the IQ and achievement tests; however, a previous experiment with children who had epilepsy showed no order effects on tests that are very sensitive to fatigue effects (Taylor-Cooke & Fastenau, 2004).

## Variables and Instruments

**Intelligence—**The *Kaufman Brief Intelligence Test* (K-BIT; Kaufman & Kaufman, 1983) was used to assess intellectual ability. This brief screening test yields an estimate of IQ based on a vocabulary subtest and a matrix reasoning subtest. It was standardized on a national sample, including 1,022 children and adolescents. The IQ composite correlates highly with global IQ scores on comprehensive child IQ tests (Kaufman & Kaufman, 1983).

**Academic achievement—**Academic achievement was assessed using six achievement tests of the *Woodcock-Johnson Psychoeducational Achievement Test Battery–Revised* (WJ-R; Woodcock & Johnson, 1989). Two tests assess receptive written language, or reading skills; these address word decoding skills (Letter–Word Identification) and reading comprehension (Passage Comprehension). Two others measure expressive written language (writing to dictation, which includes spelling, punctuation, and syntax; Dictation) and logical sentence construction (Writing Samples). Finally, there are two tests of mathematics, one measuring basic computational skills (Calculations) and the other measuring arithmetic reasoning or word problems (Applied Problems). The WJ-R is a well-validated battery of academic achievement tests that was standardized on a sample of 6,300 individuals (Woodcock & Johnson, 1989).

For each WJ-R subtest, children were classified into one of two academic achievement groups (at risk or not at risk), depending on whether their age-adjusted standard scores exceeded the predefined psychometric cutoff for LD. Three psychometric definitions for LD were examined:

1. 1.0 *SD*, or 15 points, below estimated IQ (IQ–achievement discrepancy);
2. 1.0 *SD* below the mean for the achievement test (1.0 *SD* low achievement); and
3. 1.5 *SD* below the mean for the achievement test ("1.5 *SD* low achievement).

The 1.0 *SD* cutoff used for the IQ–achievement discrepancy definition reflects the more liberal definitions of the states' criteria, in the spirit of using the discrepancy as a *screening* for possible LD. Moreover, achievement was examined as a continuous variable using the age-adjusted standard scores.

**Seizure variables—**Seizure variables consisted of seizure control, seizure type, medication status, age of onset, and current age. Seizure control was defined dichotomously depending on whether the child had had at least one seizure in the previous 12 months (active) or no seizures in the past 12 months (controlled). Seizure types (see Table 1) were reclassified into four groups:

1. absence;
2. generalized tonic–clonic (GTC) and atonic, akinetic, myoclonic (AAM);
3. simple partial and complex partial seizures (CPS); and

4. simple partial with generalization and CPS with generalization.

*Medication status* was dichotomized into presence or absence of polytherapy; thus, the small number of children who were unmedicated were combined those who were on only one medication. *Age of onset* was determined by parent report of the date of the first recognized seizure. *Current age* was defined by the child's age at the time of the neuropsychological exam.

**Attention-deficit/hyperactivity disorder—**The primary caregiver completed either the *Child Symptom Inventory–4* (CSI; Gadow & Sprafkin, 1997; children 12 and younger) or the *Adolescent Symptom Inventory–4* (ASI; Gadow & Sprafkin, 1998; children 13 and older). Both inventories are structured diagnostic interviews that follow the criteria of the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM–IV*; American Psychiatric Association, 1994). The CSI is a 97-item checklist containing symptoms of 17 behavioral disorders. The ASI is a 120-item checklist, also covering symptoms of 17 behavioral disorders. Behaviors are rated on a Likert-type scale ranging from 0 (never) to 3 (very often). Symptom severity is scored by summing item scores for each disorder. For the present study, children were classified as having ADHD if their symptom criterion score exceeded the screening cutoff that would warrant consideration of a diagnosis of ADHD.

### Statistical Analyses

Frequency analyses identified the proportion of children who were at risk for LD for each WJ-R test, for each academic domain (i.e., meeting criteria on either test or on both tests within a domain), and for any of the six WJ-R subtests. Multivariate regression analyses were used to identify the risk factors for LD; the models included seizure type, seizure control, medication status, age of onset, current age, and ADHD based on the studies reviewed in the introduction. Given the paucity of research into the predictors of academic underachievement in this population, together with the tendency of past studies to focus on only a few academic domains, all epilepsy-related predictors were included in all models even if a specific predictor had not been implicated for a specific academic area.

Even though children were screened for a diagnosis of mental retardation, 12 children who had not been formally diagnosed or classified in the schools scored below 70 on our brief screening. In post hoc analyses, these 12 were excluded from all models. Moreover, because of the relationship between IQ and achievement, the continuous models were reexamined with IQ controlled (i.e., entered in the first step).

Alpha was set to $p < .05$ for all analyses. As an indicator of effect size, the odds ratio (OR) was computed for each predictor; the OR provides an index of the strength of association and has been shown to be useful in neuropsychological research (Bieliauskas, Fastenau, Lacy, & Roper, 1997).

## Results

The standardized scores for the sample are presented in Table 2. Tables 3, 4, and 5 show test results for the IQ–achievement discrepancy, 1.0 *SD* low-achievement, and 1.5 *SD* low-achievement definitions, respectively. Each table reports the proportion of children exceeding the criterion (percentage at risk), the risk factors that were statistically significant, and the odds ratio associated with each risk factor. Comparisons between the definitions are depicted graphically in Figure 1, which shows the proportions of children exceeding the criterion organized by individual WJ-R test, academic domain, and LD definition.

## Planned Analyses

**IQ–achievement discrepancy model—**Under the IQ–achievement discrepancy definition, 48.2% (n = 79) of all children in the sample exceeded the discrepancy criterion for LD on at least one of the six WJ-R tests. For reading achievement, 12.8% of children met criterion for LD (see Table 3). On Letter–Word Identification, no risk factors were identified. On Passage Comprehension, the model could not be fit with confidence, so no risk factors could be identified for that aspect of reading.

**For math achievement, 20.1% met the criterion for LD—**On the Calculation subtest, older children were at higher risk. Moreover, primarily generalized motor seizures carried considerably more risk compared to partial seizures with or without generalization (four to five times the risk) and compared to absence seizures (twice the risk). For written language, 37.8% met the criterion for LD. On the Dictation subtest, none of the risk factors tested were statistically significant. On Writing Samples, younger children were at greater risk than older children for LD in writing.

**1.0 SD low-achievement model—**Under the low-achievement definition using a 1.0 SD cutoff, for reading achievement, 32.2% of children met criterion for LD (see Table 4). On the Letter–Word Identification subtest, earlier age of onset and comorbid ADHD emerged as risk factors. On Passage Comprehension, earlier age of onset was associated with greater LD risk. For math achievement, 38.4% met the criterion for LD. Earlier age of onset was a risk factor for both math subtests. ADHD was another risk factor, but for the Calculation subtest only. For written language, 56.1% met the criterion for LD. Under the 1.0 SD low-achievement definition, none of the risk factors reached statistical significance for either writing subtest.

**1.5 SD low-achievement model—**Under the low-achievement definition using a 1.5 SD cutoff, for reading achievement, 20.1% of children met criterion for LD (see Table 5). On the Letter–Word Identification subtest, earlier age of onset was associated with greater risk of LD. On Passage Comprehension, the model could not be fit with confidence, so no risk factors could be identified for that aspect of reading. For math achievement, 26.8% met the criterion for LD. On the Calculation subtest, children with earlier age of onset and ADHD were at greater risk for LD than were children without those risk factors. There were no risk factors associated with the Applied Problems subtest under this definition of LD. For written language, 34.8% met the criterion for LD. On the Dictation subtest, none of the risk factors tested were statistically significant. Under the 1.5 SD low-achievement definition, none of the risk factors reached statistical significance for either writing subtest.

## Achievement Scores as Continuous Variables

Maintaining achievement scores as continuous variables (with no control for IQ), the seizure risk factor was identical to the low-achievement models. Specifically, earlier age of onset was a risk factor for several subtests: Letter–Word Identification ($p$ = .003) and Passage Comprehension ($p$ = .02) in the reading domain; Calculation in the math domain ($p$ = .04); and Dictation ($p$ = .006) in the written language domain. Moreover, current age entered the model as a significant predictor for both writing subtests (Dictation, $p$ = .05; Writing Samples, $p$ = .003); lower achievement was observed in younger children, whereas higher achievement was associated with older age. ADHD was not significantly associated with any of the continuous achievement scores ($p$ > .05).

## Post Hoc Analyses

All analyses were repeated after excluding 12 children (7.3% of the sample) with K-BIT screening scores below 70. After excluding the children with low IQ from the low-achievement analyses, age of seizure onset no longer entered as a predictor of math subtests, and ADHD entered as a predictor of writing. There were no other changes on low-achievement models and no changes to discrepancy or continuous models after excluding children with low IQ.

After entering IQ in the first step of the continuous models, age of onset was no longer a significant predictor in any of the models (replaced by IQ for Letter–Word Identification, Passage Comprehension, Calculation, or Dictation). Current age varied across domains, becoming significant for Letter–Word Identification and for Calculation, becoming nonsignificant for Dictation, and staying unchanged in the other academic domains.

## Discussion

This study assessed the frequency with which children who have epilepsy meet various psychometric criteria for LD in a large and diverse sample and sought to identify risk factors that might further guide screening processes in the schools. Definitions of low achievement that did not incorporate IQ yielded the highest rates of LD overall, with the highest rates for the 1.0 *SD* low-achievement definition. Even using the more stringent IQ–achievement discrepancy definition for LD, approximately one half of the children with epilepsy (48.2%) met psychometric criteria for LD.

Discrepancies were most common in writing (38%), followed by math (20%) and reading (13%). The lower rates of reading LD by the IQ–achievement discrepancy definition compared to the low-achievement definitions might be due to the IQ measure used. The second part of the Vocabulary subtest provides children with spelling-based clues (e.g., “What is the name of a special oven used to bake bricks and pottery and spelled K __ __ N”). Thus, children with weak reading skills might not benefit from these clues to the same degree as do other children, thereby lowering their IQ estimate and reducing the discrepancy between the reading achievement scores and IQ.

These rates are fairly comparable to those obtained by Seidenberg et al. (1986) in a similar sample and with a similar LD definition (comparing achievement to an IQ-based expected score) but using a 12-point discrepancy and a briefer set of achievement measures. Seidenberg et al. obtained rates for sight reading/word attack skills (10.2%) and for spelling (23.6%) that were similar to those observed in the present study (9.8% and 28.1%, respectively); they found much higher rates for reading comprehension (17.3% vs. 5.5%) and for computational math (30.2% vs. 20.1%), perhaps reflecting the more liberal discrepancy used in that study.

The present study measured multiple dimensions of writing that have been largely neglected in past studies, which typically relied on measures of spelling to the neglect of measuring punctuation, grammar/usage, and sentence construction. When writing was conceptualized in a multidimensional manner, 38% of the children in the present study met IQ–achievement discrepancy criteria for LD in writing; using low-achievement definitions, 35% to 56% met psychometric criteria for LD in writing. Finally, past studies reported the rates of underachievement only by individual test (Seidenberg et al., 1986), but the total number of children meeting criteria for LD across academic domains was unclear. In the present study, 48% of children with epilepsy met the IQ–achievement discrepancy criterion for LD in at least one academic domain; using low-achievement definitions, 41% to 62% met psychometric criteria for LD at least one academic domain.

When IQ was factored into low achievement via the IQ–achievement discrepancy definition, seizure type was the only seizure variable to enter the model as a risk factor (non-absence generalized seizures carrying more risk than other types), and this was observed for computational math skills only. Current age was the only other risk factor, with younger children exhibiting higher rates of LD by this definition and older children exhibiting lower rates. It might be that older children have learned to compensate for their deficiencies, using other cognitive resources to adapt to their specific learning deficit. Alternatively, or additionally, older children might have had more opportunity to be identified by school personnel for educational interventions.

For definitions that did not incorporate IQ (1.0 *SD* and 1.5 *SD* low-achievement definitions), age of seizure onset was the only seizure risk factor, appearing for both reading and math domains. Similarly, when achievement was examined as a set of continuous variables (without IQ), the same seizure risk factor emerged, not only for reading and math but also for one aspect of writing. Early age of onset (especially before age 2) is often associated with broad cognitive deficits in this population, affecting both IQ and achievement. That is, children with early onset epilepsy would typically have low IQ *and* low achievement; when LD is defined as the difference between IQ and achievement, the discrepancy is small even when achievement is low. Therefore, it would appear that this risk factor did not emerge in the IQ–achievement discrepancy model because of the built-in control for IQ in the psychometric definition. In support of this conclusion, when children with low IQ screening scores were excluded from low-achievement models, age of onset no longer predicted math achievement. Similarly, when IQ was entered into the continuous models, it replaced age of onset on all four subtests predicted by that seizure variable.

For low-achievement definitions, ADHD also proved to be a robust predictor for milder levels of LD (i.e., in the 1.0 *SD* model) for reading and math, as well as for writing in the non–mental retardation range of our IQ screening. This is not surprising, given the literature supporting the comorbidity between these two conditions. The lack of a role for ADHD in more severe levels of low achievement (i.e., the 1.5 *SD* and IQ–achievement discrepancy models) lends support to the notion that achievement deficits in this population are not merely a byproduct of ADHD.

Consistent with the majority of past studies reviewed earlier, most seizure variables (medication status, seizure control, or seizure type) yielded little information for reliably identifying children who met psychometric criteria for LD in most academic domains. That is, even children who had seizure types that appeared to be less disabling (e.g., partial seizures or absence seizures), who had seizures that were well controlled by medications, or who required no more than one medication to control their seizures appeared be at equal risk for LD compared to children with more severe conditions, at least in children without mental retardation. The lack of risk factors (and, therefore, the susceptibility of all children with epilepsy) is especially true for LD in writing, which appears to be the most commonly occurring LD subtype in epilepsy, based on the present sample.

The lack of a direct relationship between seizure variables and learning difficulties highlights the importance of looking at other factors and more complex relationships. Fastenau, Dunn, and Austin (2003) presented a multifactorial model of childhood epilepsy that posits direct, mediating, and moderating relationships among neurological and seizure variables, neuropsychological functioning, and child and family psychosocial variables to help explain why some of these children have more difficulty in school than others. A recent empirical test of parts of that model confirmed that seizure variables play a minimal role in academic underachievement; instead, we observed a positive impact of a structured and supportive home environment, particularly on writing achievement (Fastenau et al., 2004). Similarly, Mitchell et al. (1991) found that seizure variables were unrelated to IQ-adjusted achievement in most domains; however, family environment (e.g., emotional climate, stimulation, parental involvement) accounted for a significant amount of variance in IQ-adjusted academic achievement in reading (word identification/word attack skills and reading comprehension) and general knowledge.

The present study demonstrates the extent of LD in children with epilepsy and the added susceptibility in children with comorbid ADHD. Moreover, compared to children in the general population, children with epilepsy have a greater prevalence of internalizing disorders (depression and anxiety), which are more likely than externalizing behaviors to go undetected, to be undertreated, and to adversely affect academic performance (Ettinger et al., 1998; Dunn, Austin, & Huster, 1999; Oxguz et al. 2002). Taken together, these findings emphasize the need to screen for learning-related disorders (LD, ADHD, and behavior problems) and to continuously monitor academic performance in children with epilepsy (Black & Hynd, 1995). Assessment should be comprehensive and should use a broad battery of academic achievement tests that sample critical domains shown to be affected in children with epilepsy.

As a limitation to the present study, IQ was not assessed with a full IQ test such as the *Wechsler Intelligence Scale for Children* (Wechsler, 1991) or the *Stanford-Binet Intelligence Scale* (Roid, 2003). Although the composite standard score on the measure used in this study correlates very highly with global IQ scores on fuller IQ tests (Kaufman & Kaufman, 1983), the reliance on knowledge of spelling for performance on the second part of the Vocabulary subtest might have resulted in underidentification of reading LD in this study when the IQ–achievement discrepancy definition was applied.

In conclusion, children with epilepsy, even in the absence of a diagnosis of mental retardation, are at dramatically increased risk for LD. Thus, a diagnosis of epilepsy (even with controlled seizures and with seizure types that are considered to be less severe) should provide sufficient cause to screen for LD in the schools.

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## Biographies

**Philip S. Fastenau,** PhD, is associate professor in the Department of Psychology at Indiana University Purdue University Indianapolis (IUPUI). His primary program of research addresses neuropsychological functioning in children with neurological disorders, and in children with epilepsy in particular. His other research focus is the development and validation of psychometric instruments.

**Jianzhao Shen,** MS, is senior biostatistician in the Department of Medicine at Indiana University School of Medicine. He currently conducts psychometric research in the area of Alzheimer's disease.

**David W. Dunn,** MD, is a professor of psychiatry and neurology at Indiana University School of Medicine. He conducts research in the behavioral aspects of childhood epilepsy and is co-director of the ADHD and Disruptive Behavior Disorders Clinic at Riley Hospital for Children.

**Joan K. Austin,** DNS, is distinguished professor at Indiana University School of Nursing. Her program of research focuses on mental health problems in children with chronic illness,

especially children with epilepsy. Address: Philip S. Fastenau, Department of Psychology, Indiana University Purdue University Indianapolis (IUPUI), 402 North Blackford Street, Room LD 124, Indianapolis, Indiana, 46202-3275; e-mail: pfastena@iupui.edu



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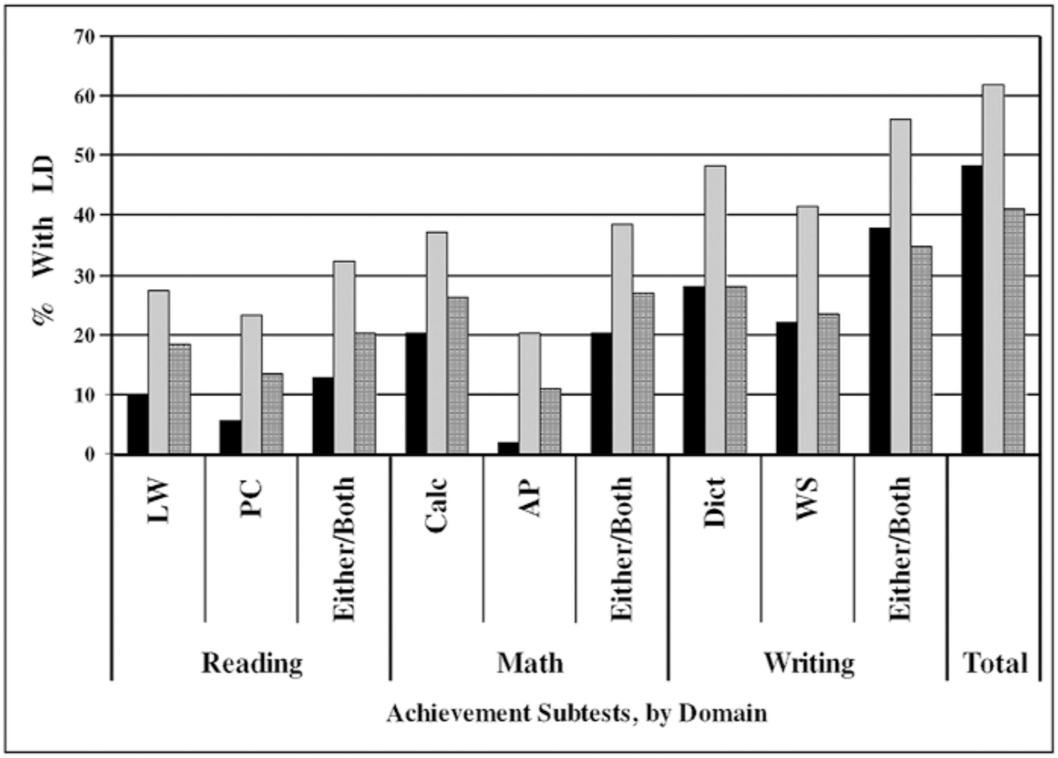


**Figure 1. Proportions of Children Meeting Criteria for LD by Academic Achievement Domain, by Test, and by LD Definition**

Note: LW = Letter–Word Identification; PC = Passage Comprehension; Calc = Calculation; AP = Applied Problems; Dict = Dictation; WS = Writing Samples; black bars = IQ–achievement discrepancy definition; gray bars = 1.0 SD low-achievement definition; striped bars = 1.5 SD low-achievement definition.

**Table 1**

Demographic and Clinical Characteristics of the Sample

| Characteristic | % | *M* | *SD* | *Mdn* | Range |
|---|---|---|---|---|---|
| Current age (years)[a] | | 11.8 | 1.8 | 11.4 | 8.8–15.0[a] |
| Age of onset (years) | | 6.5 | 3.8 | 6.9 | 0.0–13.9 |
| Duration of disorder (years) | | 5.2 | 3.9 | 4.6 | 0.3–14.4 |
| IQ (K-BIT)[b] | | 93.3 | 14.9 | 96.0 | 56–130 |
| Caregiver's education (years completed) | | 13.5 | 2.3 | 13.0 | 8–20 |
| Gender (% female) | 49.1 | | | | |
| Handedness (% left-handed) | 15.8 | | | | |
| Race | | | | | |
| European American | 91.3 | | | | |
| African American | 5.8 | | | | |
| Other/multiracial | 2.9 | | | | |
| Number of seizure types per child | | | | | |
| 1 | 78.7 | | | | |
| 2 | 19.5 | | | | |
| Missing | 1.8 | | | | |
| Primary seizure type[c] | | | | | |
| GTC | 20.2 | | | | |
| AAM | 1.2 | | | | |
| CPS | 33.9 | | | | |
| CPS-G | 16.7 | | | | |
| SPS | 7.1 | | | | |
| SPS-G | 3.0 | | | | |
| Absence | 17.9 | | | | |
| Unknown/unclassified | 0.6 | | | | |
| Etiology of seizures | | | | | |
| Idiopathic/cryptogenic | 69.9 | | | | |
| Familial | 15.4 | | | | |
| Symptomatic | 14.7 | | | | |
| Seizure control (% of group) | | | | | |
| Active | 69.0 | | | | |

| Characteristic | % | *M* | *SD* | *Mdn* | Range |
|---|---|---|---|---|---|
| Controlled | 31.0 | | | | |
| Number of current antiepileptic drugs (% of group) | | | | | |
| 0 | 4.6 | | | | |
| 1 | 78.6 | | | | |
| 2 | 14.5 | | | | |
| 3 | 2.3 | | | | |

Note: K-BIT = *Kaufman Brief Intelligence Test* (Kaufman & Kaufman, 1983); GTC = generalized tonic–clonic; AAM = atonic, akinetic, myoclonic; CPS = complex partial seizures; CPS-G = complex partial seizures with secondary generalization; SPS = simple partial seizures; SPS-G = simple partial seizures with secondary generalization.

[a]Two children were enrolled 2 months prior to their ninth birthdays, and one child turned 15 years old between enrollment and neuropsychological testing.

[b]Some children scored in the range of mild mental retardation (MR) on a brief IQ screening; however, these children were not diagnosed with MR or classified as MR by the schools.

[c]For analysis as a moderator variable, seizure type was reclassified into four groups: (a) Absence; (b) GTC/AAM; (c) SPS/CPS; and (d) SPS-G/CPS-G.

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**Table 2**

Academic Achievement Test Scores by Academic Domain and by Test

| **Test Variable** | **Observed** | |
|---|---|---|
| | **M** | **SD** |
| Reading | | |
| WJ-R Letter–Word Identification | 92.6 | 17.1 |
| WJ-R Passage Comprehension | 94.8 | 17.3 |
| Math | | |
| WJ-R Calculations | 89.6 | 20.3 |
| WJ-R Applied Problems | 98.7 | 16.3 |
| Writing | | |
| WJ-R Dictation | 84.5 | 13.6 |
| WJ-R Writing Samples | 89.2 | 19.3 |

Note: WJ-R = Woodcock-Johnson Psychoeducational Battery–Revised.

For all tests, *M* = 100 and *SD* = 15 in national standardization sample. *N* = 164.

**Table 3**

Percentage of Children Classified as At Risk by the IQ–Achievement Discrepancy Model, With Significant Risk Factors and Associated Odds Ratios

| Model | % At Risk | Risk Factor[a] | OR | 95% CI |
|---|---|---|---|---|
| Reading | | | | |
| Letter–Word Identification | 9.8 | None | | |
| Passage Comprehension | 5.5 | Undetermined[b] | | |
| Either or both subtests | 12.8 | None | | |
| Math | | | | |
| Calculation | 20.1 | Current age | 0.68 | 0.52–0.89 |
| | | Seizure type | | |
| | | Generalized vs. Absence | 1.96 | 0.57–6.67 |
| | | Generalized vs. Partial without generalization | 5.56 | 1.64–20.00 |
| | | Generalized vs. Partial with generalization | 3.85 | 1.02–14.29 |
| Applied problems | 1.8 | Undetermined[b] | | |
| Either or both subtests | 20.1 | Current age | 0.68 | 0.52–0.89 |
| | | Seizure type | | |
| | | Generalized vs. Absence | 1.96 | 0.57–6.67 |
| | | Generalized vs. Partial without generalization | 5.56 | 1.64–20.00 |
| | | Generalized vs. Partial with generalization | 3.85 | 1.02–14.29 |
| Writing | | | | |
| Dictation | 28.1 | None | | |
| Writing samples | 22.0 | Current age | 0.63 | 0.48–0.82 |
| Either or both subtests | 37.8 | None | | |

Note: Criterion set to 1.0 *SD* below estimated IQ. OR = odds ratio; CI = confidence interval. *N* = 164.

[a]Risk factors tested in the model included seizure type, seizure control, medication status, age of onset, current age, and attention-deficit/hyperactivity disorder. Please see text for details.

[b]Due to the fact that the number of children classified as at risk was low, the Passage Comprehension and Applied Problems models did not meet statistical criteria for convergence. Therefore, results are not reported for these models.

**Table 4**

Percentage of Children Classified as At Risk by the 1.0 SD Low-Achievement Model, With Significant Risk Factors and Associated Odds Ratios

| Model | % At Risk | Risk Factor[a] | OR | 95% CI |
|---|---|---|---|---|
| Reading | | | | |
| Letter–Word Identification | 27.4 | Age of seizure onset | 0.85 | 0.76–0.96 |
| | | ADHD | 2.32 | 1.06–5.11 |
| Passage Comprehension | 23.2 | Age of seizure onset | 0.86 | 0.77–0.97 |
| Either or both subtests | 32.2 | Age of seizure onset | 0.85 | 0.76–0.94 |
| | | ADHD | 2.13 | 1.00–4.54 |
| Math | | | | |
| Calculation | 37.2 | Age of seizure onset | 0.89 | 0.81–0.99 |
| | | ADHD | 2.71 | 1.31–5.61 |
| Applied problems | 20.1 | Age of seizure onset | 0.88 | 0.78–0.99 |
| Either or both subtests | 38.4 | Age of seizure onset | 0.90 | 0.81–0.99 |
| | | ADHD | 2.43 | 1.18–5.01 |
| Writing | | | | |
| Dictation | 48.2 | None | | |
| Writing samples | 41.5 | None | | |
| Either or both subtests | 56.1 | None | | |

Note: Criterion set to 1.0 *SD* below the *M* for the standardization sample on each achievement test. OR = odds ratio; CI = confidence interval; ADHD = attention-deficit/hyperactivity disorder. *N* = 164.

[a]Risk factors tested in the model included seizure type, seizure control, medication status, age of onset, current age, and ADHD. Please see text for details.

**Table 5**

Percentage of Children Classified as At Risk by the 1.5 SD Low-Achievement Model, With Significant Risk Factors and Associated Odds Ratios

| Model | % At Risk | Risk Factor[a] | OR | 95% CI |
|---|---|---|---|---|
| Reading | | | | |
| Letter–Word Identification | 18.3 | Age of seizure onset | 0.88 | 0.77–1.00 |
| Passage Comprehension | 13.4 | Undetermined[b] | | |
| Either or both subtests | 20.1 | Age of seizure onset | 0.88 | 0.78–0.99 |
| Math | | | | |
| Calculation | 26.2 | Age of seizure onset | 0.87 | 0.78–0.97 |
| | | ADHD | 2.17 | 0.99–4.72 |
| Applied problems | 11.0 | None | | |
| Either or both subtests | 26.8 | Age of seizure onset | 0.88 | 0.79–0.98 |
| Writing | | | | |
| Dictation | 28.1 | None | | |
| Writing samples | 23.3 | None | | |
| Either or both subtests | 34.8 | None | | |

Note: Criterion set to 1.5 *SD* below the *M* for the standardization sample on each achievement test. OR = odds ratio; CI = confidence interval; ADHD = attention-deficit/hyperactivity disorder. *N* = 164.

[a]Risk factors tested in the model included seizure type, seizure control, medication status, age of onset, current age, and ADHD. Please see text for details.

[b]Due to the fact that the number of children classified as at risk was low, the Passage Comprehension model did not meet statistical criteria for convergence. Therefore, results are not reported for this model.