Lateralization of Temporal Lobe Epilepsy and Learning Disabilities, as Defined by Disability-related Civil Rights Law

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Summary: *Purpose:* Epilepsy research has identified higher rates of learning disorders in patients with temporal lobe epilepsy (TLE). However, most studies have not adequately assessed complex functional adult learning skills, such as reading comprehension and written language. We designed this study to evaluate our predictions that higher rates of reading comprehension, written language, and calculation disabilities would be associated with left TLE versus right TLE.

Methods: Reading comprehension, written language, and calculation skills were assessed by using selected subtests from the Woodcock-Johnson Psycho-Educational Tests of Achievement–Revised in a consecutive series of 31 presurgical patients with TLE. Learning disabilities were defined by one essential criterion consistent with the Americans with Disabilities Act of 1990. Patients had left hemisphere language dominance based on Wada results, left or right TLE based on inpatient EEG mon-

itoring, and negative magnetic resonance imaging (MRI), other than MRI correlates of mesial temporal sclerosis.

Results: Higher rates of reading comprehension, written language, and calculation disabilities were associated with left TLE, as compared with right TLE. Nearly 75% of patients with left TLE, whereas fewer than 10% of those with right TLE, had at least one learning disability.

Conclusions: Seizure onset in the language-dominant hemisphere, as compared with the nondominant hemisphere, was associated with higher rates of specific learning disabilities and a history of poor literacy or career development or both. These results support the potential clinical benefits of using lateralization of seizure onset as a predictor of the risk of learning disabilities that, once evaluated, could be accommodated to increase the participation of patients with epilepsy in work and educational settings. **Key Words:** Epilepsy—Learning disabilities—Americans with Disabilities Act.

Acquiring adult literacy or learning skills is a primary mission of childhood education. The clinical importance of adult learning skills can be appreciated from the definition of literacy as "an individual's ability to read, write, and speak . . . , compute and solve problems at levels of proficiency necessary to function on the job, in the family of the individual, and in society" (1). A recent population-based epidemiologic survey (2) underscores the importance of adult literacy in that adults with poor reading comprehension-, written language–, and calculation-related learning skills were noted to have significantly lower rates of both high school graduation and participation in work or school settings. These same adults also had higher rates of physical, mental, or health-related impairments, as well as higher rates of poverty (2).

Epilepsy disrupts the acquisition of child and adult literacy or career development skills or both in patients without mental retardation. Pediatric and adult epilepsy research has identified increased risks of poor educational achievement (e.g., 3,4), subsequent adult unemployment or underemployment, and lower income (5,6). As predicted by material-specific theories of hemispheric specialization, Hermann et al. (7) found that reading comprehension was more impaired (as were other language-related skills) in patients with left hemisphere language dominance and left temporal lobe epilepsy (TLE) than in those with right TLE. Hermann et al. (8) also reported that the presence versus absence of mesial temporal/hippocampal sclerosis (MTS) in those with left TLE was associated with greater reading-comprehension impairments.

The relation between specific learning disorders and TLE or other epilepsies remains uncertain, in part because researchers have used different definitions and measures of specific learning skills (9). Traditional definitions of

specific learning disorders have served as essential eligibility criteria in child special education law (10,11) and in child and adult mental health diagnostic classification systems (12,13). These definitions presume that diagnosis of a learning disability is appropriate only if a significant discrepancy exists between IQ (i.e., mental aptitude) and specific learning (i.e., specific academic achievement) skills in reading, writing, arithmetic, or communication (14,15). However, this definition has not been validated because researchers have not identified fundamental differences in learning skills between persons with and without significant IQ/academic skill discrepancies (e.g., 10,16,17). Further, the use of traditional definitions may be particularly inappropriate in patients with lateralized TLE who become seizure free after epilepsy surgery. These patients' presurgical IQ scores may be underestimated, because postsurgical increases in IQ scores often exceed the expected increases in IQ scores because of practice effects from repeated IQ testing alone (18,19). As a result, use of traditional definitions of learning disabilities may underestimate the relation between learning disabilities and TLE.

Alternative definitions of learning disabilities are specified in adult disability laws, such as the Rehabilitation Act of 1973 (20) and the Americans with Disabilities Act of 1990 (ADA) (21). These latter definitions require "substantial limitation of major life activities" (22), without any IQ/academic skill discrepancies. Learning is one major life activity represented by specific learning, academic, or literacy skills, such as reading comprehension or written communication. "Substantial limitations" have been interpreted in recent U.S. federal court rulings (23) as complex functional learning skills that fall "below-the-average-peer" in the general population. The latter definition is more appropriate than traditional definitions of disability for adults with epilepsy-related learning disabilities that may affect their participation in work or adult educational settings.

By using a definition of learning disability consistent with adult disability rights law, we predicted that higher rates of reading comprehension, written language, and calculation disabilities would be associated with left TLE, as compared with right TLE, based on empirical research and theories of hemispheric specialization. Post hoc analyses also were conducted, as discussed later.

METHODS

Subjects

In this retrospective, cross-sectional, and observational study, subjects consisted of a consecutive series of 31 pre–epilepsy surgery candidates who met the following inclusion criteria: (a) completion of reading comprehension, written language, and written calculation subtests from the Woodcock-Johnson Psycho-Educational Battery–Revised (24) as part of a presurgical neuropsychological evaluation; (b) chronologic age between 16 and 60 years; (c) WAIS-R (25) Full Scale IQ of ≥ 70; (d) Wada test results indicating left hemisphere speech dominance; (e) negative MRI other than MRI correlates of MTS; and (f) left or right TLE based on inpatient video/EEG depth, subdural, and/or scalp monitoring results. Patients were excluded if they had a history of any of the following: mental retardation, possible dementia, primary generalized epilepsy, bilateral onset of TLE, or macroscopic CNS lesions based on available clinical pathology or MRI findings or both (except for MRI correlates of MTS). This study received Institutional Review Board approval.

Description of groups by lateralization and MRI correlates of TLE

Lateralization of TLE was based on inpatient EEG monitoring. We identified 19 patients with left TLE and 12 patients with right TLE. We also conducted post hoc analyses to evaluate the possible confounding influence of abnormal MRI-MTS signal correlates or MTS surgical histopathology for the left TLE group, as compared with right TLE group, given the potentially adverse impact of MTS on language-related skills (7,8).

MRI correlates of MTS have been defined by loss of hippocampal volume, loss of defined internal morphologic structures, increased T_2-weighted signals, and decreased T_1-weighted signals (26). To evaluate severity of abnormal MRI correlates of MTS in our patients, we measured MRI correlates of MTS based on established guidelines (26). With a 1.5-T GE Signa MRI Scanner (GE Medical Systems, Milwaukee, WI, U.S.A.), imaging was available from three image-acquisition methods based on continuous coronal slices perpendicular to the long axes of the hippocampus, with thickness of 3.0 mm without skips and based on axial images taken orthogonally to these axes. We have previously used these image-acquisition methods in neuroimaging research on the reliability and validity of hippocampal volumetry, based on established protocols (27–30). The T_1 series was characterized by TR of 500; TE of 8; FOV, 22×22 cm; and matrix, 256×160. The T_2 sequence had TR of 4,000; TE of 105; FOV, 22×22 cm; and matrix, 256×192. Additionally, imaging based on fluid-attenuated inversion recovery (FLAIR) sequences was available, with TR of 1,000; TE of 120; TI of 2,200; FOV, 22×22 cm; and matrix, 22×22.

To evaluate interrater reliability of MRI signal correlates of MTS, two investigators, who were blind to clinical MRI and pathology reports, independently rated MRI images for the lateralized presence of either (a) no abnormal MRI correlates of MTS; (b) mildly abnormal MRI correlates of MTS; or (c) markedly abnormal MRI correlates of MTS. Interrater reliability was good for measures of abnormal MRI correlates of right MTS (Spearman's r (r^s) = 0.717; p < 0.01) and left MTS (r^s = 0.715;

p < 0.01). All interrater disagreements were resolved by consensus, resulting in final ratings that were used in post hoc analyses of ipsilateral TLE and markedly abnormal MRI-MTS signal correlates (i.e., ipsilateral TLE/MRI-MTS correlates).

To verify whether MRI-MTS signal correlates were consistent with clinical pathology, we reviewed available histopathology findings based on specimens obtained from standard surgical resection of either temporal lobe (31). On the left, 3.0 to 3.5 cm of the inferior and middle temporal gyri was removed, as were the basolateral amygdala and 4 cm of the hippocampus. On the right, 4 cm of the hippocampus also was removed, as well as the basolateral amygdala through the pathway created by an en bloc excision of 5 cm of the inferior and middle temporal gyri. Two independent pathologists reviewed and evaluated surgical specimens. Clinical pathology findings were classified as consistent with no abnormal histopathology; mild or more severe neuronal/gliotic histopathologic findings consistent with MTS; and/or microscopic dysplasia, neoplasia, or other nonsclerotic histopathologies. Surgical pathology reports were not available for all patients because eight patients were awaiting surgical resection, and five patients had chosen an alternative surgical treatment (i.e., implantation of a vagus nerve stimulator).

In the left TLE group, mild or more severe histopathologic findings consistent with MTS were identified in the specimens of eight patients; one specimen had no abnormal histopathology. In the right TLE group, mild or more severe histopathologic findings consistent with MTS were identified in eight patients. One specimen had "dual pathologies," characterized by both "microscopic cortical dysplasia" and at least mild histopathologic findings consistent with MTS (32). Thus no evidence was found of microscopic dysplasia, neoplasia, or other nonsclerotic pathology except for a single specimen with dual pathologies.

Table 1 provides subjects' demographic (gender, hand dominance, education, age), general cognitive (WAIS-R Full Scale IQ), and epilepsy-related (age at seizure onset, duration of seizures) characteristics for the left and right TLE groups.

Description of academic achievement tests

The Woodcock-Johnson Psycho-Educational Tests of Achievement–Revised (WJ-R; 24) is a norm-referenced battery of academic achievement subtests of reading, written language, and written calculation skills. Given our interest in the evaluation of impairment of complex functional adult learning skills, we selected the WJ-R Passage Comprehension, Writing Samples, and Calculation subtests.

The WJ-R Passage Comprehension subtest assesses reading comprehension of sentences or short passages by requiring patients to provide a missing, yet contextually appropriate word. On the WJ-R Writing Samples subtest, patients' quality of communication in written sentences is evaluated without penalty for spelling, capitalization, punctuation, or usage errors. We believe these subtests provide more comprehensive assessment of adult literacy skills than do academic achievement screening tests that assess only oral reading or written spelling of single words. The WJ-R Calculation subtest assesses patients' knowledge and skill in solving written addition, subtraction, multiplication, and division problems. Patients' raw scores on these academic subtests yield age-based, norm-referenced percentile scores of their rank as compared with their same-aged peers in the general population (24).

TABLE 1. *Characteristics of left TLE and right TLE groups*

Characteristics	Lateralization of TLE				p Value
	Left TLE (n = 19)		Right TLE (n = 12)		
Gender (n/n: female/male)	10/9		7/5		NS[a]
Handedness (n/n: right/left)	16/3		10/2		NS[b]
Education (m; SD; yr)	14.00	2.60	14.75	1.71	NS[c]
Age (m; SD; yr)	31.84	9.92	37.58	10.79	NS[c]
WAIS-R Full Scale IQ (m; SD)	85.53	9.79	91.31	9.20	NS[c]
Seizure duration (m; SD; yr)	17.84	10.51	24.58	12.84	NS[c]
Age at seizure onset (m; SD; yr)	14.16	9.70	13.17	11.02	NS[c]
Ipsilateral TLE/MRI-MTS (n/n: yes/no)[d]	7/12		6/6		NS[a]
Ipsilateral TLE/MTS pathology (n/n: yes/no)[e]	8/9[f]		8/9[g]		NS[b]

TLE, temporal lobe epilepsy; MRI, magnetic resonance imaging; MTS, mesial temporal sclerosis.
[a] χ^2 test of association.
[b] Two-tailed Fisher's exact test.
[c] Two-tailed independent sample t test.
[d] Ipsilateral TLE/MRI-MTS, markedly abnormal ipsilateral TLE/MRI-MTS signal correlates.
[e] Ipsilateral TLE/MTS pathology, mild or more severe MTS surgical histopathology.
[f] Analysis includes one specimen without any surgical histopathology.
[g] Analysis includes one specimen with dysplasia and MTS surgical histopathology.

Definition of disability

We defined a specific learning disability as skills that fall "below the average peer's skills" to be consistent with an essential eligibility criterion under adult disability rights law (20–22) and federal court rulings (e.g., 23), rather than the traditional definition based on IQ-specific academic skill discrepancies. Thus we defined a specific learning disability by an age-based WJ-R Passage Comprehension, Writing Samples, or Calculation subtest percentile score that fell below the 20th percentile, which would be ~1 standard deviation below patients' same-aged, normative peers.

To determine the functional impact of learning disabilities on patients' literacy or career development, we created a post hoc categorical measure of the presence or absence of a history of "poor literacy and/or career development." The presence of the latter composite risk factor was based on a history of one or more of the following specific risk factors, including (a) neither graduating from high school nor obtaining a GED, (b) requiring alternative or special educational instruction, and/or (c) repeating or dropping grades or courses.

Statistical analyses

Fisher's exact test was used to evaluate predictions that left TLE, compared with right TLE, would be associated with higher rates of reading comprehension, expressive writing, and written calculation disabilities. Independent two-sample t test, χ^2 test of association, and Fisher's exact test analyses were used to assess the presence of other possible group differences across demographic, general cognitive, and epilepsy-related characteristics.

After our initial analyses identified higher rates of learning disabilities in the left TLE group, we conducted four post hoc analyses. First, we conducted power analyses to evaluate the probability of our analyses detecting significant results this large regarding the association of learning disabilities and lateralization of TLE.

Second, we used a χ^2 test of association to evaluate whether different rates of markedly abnormal ipsilateral TLE/MRI-MTS signal correlates would be found in the left TLE or right TLE groups. Similarly, we conducted a third post hoc analysis, which consisted of a Fisher's exact test to evaluate whether different rates of MTS sur-

gical histopathology would be found in the left TLE group, as compared with the right TLE group. If these post hoc analyses produced significant results, then MRI-MTS correlates or MTS surgical histopathology could be implicated as confounding factors associated with differences observed in the rates of learning disabilities in the TLE groups.

Finally, we used Fisher's exact test to evaluate the potential functional impact of the higher rate of learning disabilities in the left TLE versus the right TLE groups. Specifically, we evaluated whether, as would be expected, a higher rate of poor literacy or career development would be associated with left TLE and its associated higher rates of learning disabilities.

RESULTS

TLE group comparisons

Results of group analyses (see Table 1) did not reveal any significant differences between the left TLE and right TLE groups across demographic (age, gender, hand dominance, and education), general cognitive (WAIS-R Full Scale IQ), and epilepsy-related (age at seizure onset, duration of seizures) characteristics.

Other TLE group post hoc analyses are discussed later.

Analyses of a priori predictions about group comparisons

Analyses using Fisher's exact test revealed that significantly higher rates of specific learning disabilities occurred with dominant hemisphere epilepsy. Disabilities were associated more with left TLE than with right TLE [Table 2; i.e., reading comprehension (left TLE, 52.6%; right TLE, 8.3%; p = 0.014), written language (left TLE, 42.1%; right TLE, 8.3%; p = 0.050), and calculation (left TLE, 47.4%; right TLE, 0.0%; p = 0.005)]. Overall, at least one learning disability was identified in 73.7% of patients with left TLE, whereas only 8.3% of patients with right TLE were similarly identified.

The patterns of different learning disabilities for the left TLE group were as follows: five (26.3%) of 19 patients had all three specific learning disabilities, two (10.5%) had reading comprehension and written language disabilities,

TABLE 2. *Rates of learning disabilities in left TLE and right TLE groups*

Woodcock-Johnson-Revised (WJ-R) Tests	Left TLE (n = 19)		Right TLE (n = 12)		p Value[a]
	LD+	LD−	LD+	LD−	
Passage Comprehension (n)	10	9	1	11	0.014
Writing Samples (n)	8	11	1	11	0.050
Calculation (n)	9	10	0	12	0.005

LD, learning disability; TLE, temporal lobe epilepsy; LD+, learning disability present (i.e., percentile score ≤20% on WJ-R subtest); LD-, learning disability absent (i.e., percentile score >20% on WJ-R subtest).
[a]One-tailed Fisher's exact test used to evaluate directional predictions.

and one (5.3%) had reading comprehension and calculation disabilities. Furthermore, three (15.8%) of 19 had isolated calculation disabilities, two (10.5%) had isolated reading comprehension disabilities, and one (5.3%) had isolated written language disabilities. The most frequent subtype of learning disability was concurrent reading comprehension and written language disabilities (with or without concurrent calculation disabilities), which was identified in seven (36.8%) of 19 patients with left TLE. In the right TLE group, one (8.3%) of 12 had both reading comprehension and written language disabilities, and none of 12 had a calculation disability.

Analyses of post hoc group comparisons

Given the small group sizes, we conducted post hoc power analyses with results providing general support in regard to the association of lateralization of TLE and rates of learning disabilities in reading comprehension (power = 0.810), calculation (power = 0.948), and written language (power = 0.584).

We conducted a post hoc analysis to evaluate whether the rates of markedly abnormal ipsilateral TLE/MRI-MTS signal correlates were different for the left TLE and right TLE groups. A χ^2 test of association revealed no significant differences (p = 0.710) in the rates of markedly abnormal ipsilateral TLE/MRI-MTS correlates for the right versus the left TLE groups (see Table 1). Specifically, six (50.0%) of 12 patients in the right TLE group, as compared with seven (36.8%) of 19 in the left TLE group, were found to have markedly abnormal ipsilateral TLE/MRI-MTS signal correlates. Further, we found no significant differences (p = 1.00) in the rates of the presence of mild or more severe MTS surgical histopathology associated with the left TLE group, as compared with the right TLE group (see Table 1). Indeed, we identified the same number of participants in both the left and right TLE groups with either MTS or other surgical histopathologies. Thus lateralization of TLE was associated with different rates of learning disabilities, without any evidence of between-group differences in lateralization of MTS histopathology, MRI-MTS signal correlates, or age at onset of seizures.

Regarding the potential functional impact of the higher rates of learning disabilities associated with left TLE, Table 3 provides results of a post hoc Fisher's exact test. We found a significantly higher rate (p = 0.023) of the composite risk factor of a history of "poor literacy and/or career development" in the left TLE group, as compared with the right TLE group. Of the three specific risk factors that made up the composite risk factor, a significantly higher rate (p = 0.014) of a history of "requiring past alternative or special educational instruction" was found in the left TLE group versus the right TLE group (see Table 3).

TABLE 3. *Rates of "poor literacy or career development" in left and right TLE groups*

Composite and specific risk factors	Lateralization of TLE		
	Left TLE	Right TLE	p Value[a]
Poor literacy or career development? (n/n: Yes/No)	13/6	3/9	0.023
Special/Alternative education? (n/n: Yes/No)	10/9	1/11	0.014
Repeated/Dropped grades/classes? (n/n: Yes/No)	5/14	2/10	NS
High school graduate? (n/n: Yes/No)[b]	16/2[b]	12/0	NS

TLE, temporal lobe epilepsy.
[a]One-tailed Fisher's exact test used to evaluate directional predictions.
[b]Analysis excluded one student who was attending high school at time of testing.

No significant group differences were found in the rates of the other specific risk factors of either "not graduating from high school" or "repeating or dropping grades or courses" (see Table 3).

DISCUSSION

We designed this retrospective cross-sectional study to evaluate whether adults with left TLE, as compared with those with right TLE, would have higher rates of reading comprehension, written language, and calculation disabilities. Impairment was defined by the "below-the-average-peer" definition, which is one essential disability eligibility criterion under current adult disability rights law (21–23), rather than by the traditional IQ/academic skill discrepancy criterion used in child special education law (10,11) and in child and adult mental health diagnostic classification systems (12,13). Consistent with a priori predictions, higher rates of these specific learning disabilities were associated with left TLE, as compared with right TLE. Overall, nearly 74% of the left TLE group, but fewer than 9% of the right TLE group, were found to have at least one learning disability.

Post hoc power analyses provided further support for significantly higher rates of reading comprehension, calculation, and written language disabilities in left versus right TLE. We found stronger confirmation that lateralization of TLE was associated with higher rates of reading comprehension and calculation disabilities, as compared with written language disabilities. We did not find any statistically significant group differences for various demographic (age, gender, hand dominance, and years of education), general cognitive (WAIS-R Full Scale IQ), or epilepsy-related (age at seizure onset, and duration of seizures) characteristics. However, any conclusions about whether lateralized hemispheric dysfunction causes learning disabilities must be qualified because multiple factors

have been associated with learning deficits in epilepsy, such as various psychosocial (34), medication (e.g., 35), and epilepsy-related factors. Specific epilepsy-related factors include seizure type (36), transient cognitive impairment (37), and correlates of MTS (e.g., 8,38–40).

Our results may differ from those reported by Hermann et al. (7,8) for several reasons. First, we used a definition of disability specified in disability-rights law. Second, we used analyses of between-group differences based on their rates of learning disabilities rather than based on their median or mean between-group differences. Third, we measured more complex literacy skills than did Hermann et al. (7,8).

Similar to our findings, Hermann et al. (7) identified greater median impairments in reading comprehension in patients with left hemisphere language dominance and left TLE versus right TLE. These researchers did not classify patients by the presence of MTS or MRI-MTS correlates. In contrast to our study, they did not evaluate calculation and written language literacy–related skills.

In a subsequent, larger study, Hermann et al. (8) found greater mean impairments in reading comprehension in patients with left TLE with MTS, as compared with those without MTS or those with right TLE with or without MTS. These researchers also reported that the presence of MTS histopathology, regardless of lateralization of TLE, was associated with greater impairment of oral reading of single words. They reported that neither MTS histopathology nor lateralization of TLE was associated with impairment of written spelling of single words or written calculation. However, they used a simple academic achievement screening measure that does not assess more complex written language literacy–related skills. In contrast, we found that lateralization of TLE (but not the presence of MTS, MRI-MTS correlates, age at seizure onset, or duration of seizures) was associated with higher rates of reading comprehension, written language, and calculation disabilities. However, Hermann et al. (8) did not evaluate whether their observed significant group mean differences in, for example, age at seizure onset (as compared with the presence of MTS histopathology or lateralization of TLE) could better account for these group mean differences.

We agree with Hermann et al. (8), who stated " [we] do not believe that the generalized neuropsychological effects that accompany the syndrome of MTLE are attributable to the consequences of hippocampal sclerosis per se. The earlier age at onset (and longer duration) associated with MTLE raises the possibility that the generalized neuropsychological impairments may be attributable to the more diffuse neurobiological consequences associated with increasing years of intractable seizure activity or particular types of seizure activity (e.g., secondary generalized seizures), more exposure to antiepileptic medications, or other associated consequences of medication-resistant epilepsy." (p. 374)

However, we do not agree that sufficient empirical support exists for the specific assertion of Hermann et al. (8) that MTS should be considered the "primary marker" (p. 374) for MTLE, in the absence of further analyses of other epilepsy-, medication-, or neurobiologic-related factors. Of course, researchers continue to investigate whether MTS is a cause and/or a consequence of both of other neurobiologic or epilepsy-related factors (38–40).

Other well-designed studies (e.g., 9,41,42) of patients with left hemisphere language dominance and lateralized TLE have investigated learning disability subtypes by using academic achievement screening measures, such as oral reading and written spelling of single words rather than more complex adult learning or literacy skills. For example, although Breier et al. (9) used alternative disability definitions and academic screening measures, they also found that reading- and writing-related disabilities were the most common learning disabilities in patients with TLE, consistent with our current findings.

In the current study, we found that lateralization of TLE in the language-dominant hemisphere was associated with a higher risk of specific learning disabilities, consistent with the results of several epilepsy surgery studies. For example, extraoperative intracerebral stimulation of selected anterior (i.e., inferior frontal) and posterior temporal (i.e., temporoparietal) language-dominant hemispheric areas has been shown to produce temporary arrest of reading comprehension, written language, and/or calculation in patients with epilepsy (e.g., 43–46).

Higher rates of specific disabilities in reading (e.g., 47–50), calculation (51–53), and writing (54–56) have been more frequently identified in adults with acquired nonepileptogenic lesions in the language-dominant than in the nondominant hemisphere. Although bilateral hemispheric activation has been observed during learning performances based on functional neuroimaging, researchers have identified relatively greater activation in primary anterior and posterior language areas in the language-dominant hemisphere in adults with developmental dyslexia (e.g., 57), acquired nonepileptogenic alexia (58), and acquired nonepileptogenic acalculia (52). As our patients with left hemisphere language dominance and either left or right TLE were found to have language-related learning disabilities, our results are consistent with the conclusions of Hecaen (53), who asserted that language- and nonlanguage-based hemispheric syndromes may arise from selective impairments of "a plurality of mechanisms" represented in either the language-dominant or the nondominant hemisphere. Researchers continue to evaluate the relative validity of traditional "material-specific" theories (e.g., 59) versus recent "processing-specific" (e.g., 60,61) theories of hemispheric specialization.

This study with patients who have lateralized TLE is unique in providing data regarding rates of specific

learning disabilities defined by functional learning skills that fall "below the average peer," which is an essential disability eligibility criterion under current adult disability rights law (20–23). Furthermore, we found support for the functional impact of learning disabilities in the left TLE group, in that these patients also had higher rates of "poor literacy and/or career development," particularly for a history of "requiring alternative or special educational instruction." Our results further support prior studies of literacy (2) and epilepsy educational or vocational outcome (3–6) identifying relations among disability, literacy, and/or career development.

We believe that these results provide support for further clinical research using definitions and measures that are more sensitive and legally relevant to complex functional adult learning or literacy skills. First, we argue against the use of traditional "IQ/academic skill discrepancy" definitions of learning disability because of the lack of empirical support (10,17), even though clinicians continue to use traditional definitions in child special education (10) or adult and child mental health settings (12,13). These traditional definitions are especially inappropriate for patients with epilepsy whose "true" intelligence may be underestimated by their pre-epilepsy surgery IQ scores, given that their postepilepsy surgery increases in IQ scores often exceed those expected increases that are attributable to test–retest practice effects alone (18,19).

Second, we argue against the continued use of simple screening measures of specific learning skills because they neither fully evaluate the complex learning skills required of adult students or workers, nor do such measures provide adequate evaluation of functional literacy, which is an essential disability eligibility criterion under current US disability rights law. In either case, the continued use of inappropriate definitions and measures of learning skills will limit the usefulness of research regarding the relations among epilepsy, learning disabilities, and educational or vocational outcomes. Such practices also could preclude individuals with epilepsy from receiving appropriate disability-related eligibility evaluations and school or work accommodations.

Our findings support further research on the potential value of evaluating functional learning skills within the context of each patient's specific daily educational- or work-related functional learning demands. Furthermore, the practical value of lateralization of TLE as a readily available, noninvasive, clinical predictor of risk of learning disabilities is important in avoiding delays in the identification of learning disabilities and provision of possible accommodations, regardless of surgical decisions.

If a patient is found to have learning disabilities, then disability-related educational or work accommodations could be recommended and implemented. For example, patients found to have reading comprehension disabilities could benefit from reasonable accommodations, such as providing oral rather than written communication of health information, job duties, and adult educational lessons. Accommodations for patients with calculation disabilities could include simply providing calculators to support accurate completion of adult job or educational calculation assignments. Patients with written language disabilities could benefit from accommodations such as oral dictation to a tape recorder or use of a typing service for answers to educational test questions or to produce work-related reports or memoranda.

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