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PREDICTION OF LEVEL AND PATTERN  
OF INTELLIGENCE TEST PERFORMANCE

IN CHILDREN WITH LATERALIZED TEMPORAL LOBE EPILEPSY

MELANIE ANNE FERGUSON

A Thesis submitted in partial fulfilment  
of the requirements for the Degree of  
MASTER OF SCIENCE

from

Saint Mary's University

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## ABSTRACT

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PREDICTION OF LEVEL AND PATTERN  
OF INTELLIGENCE TEST PERFORMANCE  
IN CHILDREN WITH LATERALIZED TEMPORAL LOBE EPILEPSY

October 20, 1982

The present study attempted to identify valid predictors of the level and pattern of Wechsler intelligence test performance in children with lateralized temporal lobe epilepsy of unknown etiology. Six seizure-related variables (seizure type, seizure frequency, number of different types of anti-convulsant medication required to control the seizures, types of EEG abnormality, age of onset of the seizure disorder, and lateralization of the epileptiform activity) were evaluated as predictors of Full-scale IQ. Three variables (lateralization, age on onset, and severity of cerebral pathology) were evaluated as predictors of the relative magnitudes of Verbal IQ and Performance IQ. The number of anticonvulsants required to control seizures was significantly related to Full-scale IQ and accounting for 28% of the variance in the Full-scale IQ scores. Seizure type, seizure frequency, types of EEG abnormality, age of onset, and lateralization did not contribute significantly to the amount of explained variability in Full-scale IQ. There was a nonsignificant trend towards a relationship

between the lateralization of epileptiform activity and the relative magnitudes of Verbal IQ and Performance IQ.

Differences between the left and right temporal groups were in the expected direction on all but one of the Verbal and Performance IQ and subtest measures. No association was found between either the age of onset or severity of cerebral pathology and the relative magnitudes of Verbal IQ and Performance IQ. Methodological problems were considered in a discussion of these results.

Most of the children in the study were not significantly impaired intellectually, as evidenced by the fact that only four subjects in the total sample ( $n=26$ ) demonstrated Full-scale IQ scores which were below the Average range. In the left temporal group, nine of the twelve subjects demonstrated a lower Verbal IQ while; in the right temporal group, seven subjects demonstrated a lower Verbal IQ and seven subjects demonstrated a lower Performance IQ. It was concluded that, in terms of pattern of intelligence test performance, there is a trend toward a lower Verbal IQ in children with temporal lobe epilepsy maximally involving the left hemisphere, and no trend toward a particular pattern of performance in children with temporal lobe epilepsy maximally involving the right hemisphere. The results of the present study were discussed in relation to other findings in the neuropsychological literature.

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## INTRODUCTION

Children with temporal lobe epilepsy have been found, as a group, to have more behavioral and school-related problems than either children without epilepsy or children with generalized epilepsy (Stores, 1973; Stores, 1977; Stores and Hart, 1976; Stores & Piran, 1978). At the same time, many children with temporal lobe epilepsy have been found to have no such difficulties. Stores (1978) has emphasized the importance of identifying those children who are particularly predisposed to have problems so that preventive educational and psychiatric measures can be introduced at an early age when they are most needed.

In addition to identifying those children who may be at risk, it would be useful to be able to identify the types of deficits to which a particular child is predisposed. Several studies in the neuropsychological literature have indicated that children with lateralized cerebral dysfunction have characteristic patterns of cognitive impairment associated with the side of the brain which is maximally involved (Annett, Lee, & Ounsted, 1961; Fedio & Mirsky, 1969; Kershner & King, 1974). Children with left hemisphere involvement have been found, as a group, to have problems in processing verbal information while children with right hemisphere involvement have been found, as a

group, to have problems in processing nonverbal information. On an individual basis, however, the lateralization of brain dysfunction is not a reliable predictor of the pattern of cognitive impairment. In a study of children with temporal lobe epilepsy and lateralized electroencephalographic (EEG) abnormalities, for example, the patterns of impairment were found to be reversed (verbal deficits with right hemisphere abnormality, nonverbal deficits with left hemisphere abnormality) in approximately one-third of the children in both the left- and right-lateralized groups (Fedio & Mirsky, 1969).

Knowledge that a child has temporal lobe epilepsy, and that the left or right hemisphere is maximally involved, does not appear to be sufficient information for clinical purposes. The present investigation is an attempt to identify a number of variables which might improve the predictability of the level (Part One) and pattern (Part Two) of intelligence test performance in children with temporal lobe epilepsy which maximally involves one side of the brain.

PART ONE. PREDICTION OF LEVEL OF INTELLIGENCE TEST  
PERFORMANCE IN CHILDREN WITH LATERALIZED TEMPORAL  
LOBE EPILEPSY

Selection of Predictors

On the basis of the theoretical and empirical neuropsychological literature, six seizure-related variables have been identified for the present investigation as possible predictors of the level of intelligence test performance in children with lateralized temporal lobe epilepsy. These six seizure-related variables are seizure type, seizure frequency, number of different types of anticonvulsant medication required to control the seizures, types of EEG abnormality, age of onset of the seizure disorder, and lateralization of the epileptiform activity.

Seizure Type. While temporal lobe epilepsy is generally associated with psychomotor seizures, the two are not necessarily equivalent (Dodrill, 1981). It is possible for a child with temporal lobe epilepsy to be subject to other types of seizures in addition to the characteristic psychomotor type. Adults with psychomotor seizures of unknown etiology have been found to perform at essentially the same level as adults without epilepsy on intelligence

and neuropsychological test batteries, while those with either major motor or mixed (major motor and psychomotor) seizures of unknown etiology have been found to perform at significantly lower levels (Klove & Matthews, 1974). It might be expected, therefore, that a child who has, or has had, both major motor and psychomotor seizures will demonstrate a significantly lower level of intelligence test performance than the child with psychomotor seizures alone.

Seizure Frequency. A higher seizure frequency may be associated with a lower level of intellectual functioning on the basis of the severity of the underlying brain disorder, or as a result of a deterioration of brain functions due to recurrent seizures. In adults with major motor seizures of known and unknown etiology, those with high seizure frequency (more than one seizure per month) have been found to perform significantly more poorly as a group on intelligence and neuropsychological test batteries than those with low seizure frequency (one seizure per four to six months), while those with moderate seizure frequency (one seizure per one to three months) have been found to occupy an intermediate position between the high and low frequency groups (Dikmen & Matthews, 1977). One might expect to find a similar effect for seizure frequency (on the level of intellectual functioning) in children with

temporal lobe epilepsy of unknown etiology.

Number of Anticonvulsants. In reviewing the literature on anticonvulsant medication, Dikmen and Matthews (1977) and Dodrill (1981) have concluded that, even within a toxic range, the deleterious effect of anticonvulsants on the intellectual functioning of adults is negligible. In children with epilepsy, phenytoin (Dilantin) has been found to be significantly associated with lower reading skills and nonsignificantly associated with measures of inattentiveness (Stores, 1978). There are, however, a number of methodological problems involved in assessing the possible deleterious effects upon cognitive functioning of certain levels or types of anticonvulsant medication (Dodrill, 1981). An alternative approach would be to consider as an index of the controllability of seizures the number of different types of anticonvulsant prescribed to a patient. Since an additional type of anticonvulsant is prescribed when the drug presently used is not effective within a nontoxic range of dosage, it might be argued that a child who requires two or three different types of anticonvulsant has a greater degree of neurological impairment than a child who requires only one type of anticonvulsant for effective seizure control. It might therefore be expected that the child who requires more than one type of anticonvulsant will

demonstrate a lower level of intellectual functioning.

Types of EEG Abnormality. Dodrill (1981) has examined the findings from studies of the psychological correlates of a number of seizure history variables including etiology, age at onset and duration of the disorder, seizure type and frequency, anticonvulsants and EEG variables. He has concluded that, among these, the EEG variables demonstrate the strongest relationships with intelligence and neuropsychological test performance. Substantially decreased levels of performance have been found in adults with epilepsy in association with epileptiform discharges and with slower rhythm frequencies. It might be argued that the child with both a temporal lobe spike discharge and slowing in the EEG will demonstrate a greater level of cognitive impairment than the child with the epileptiform discharge alone.

Age of Onset of the Seizure Disorder. Several theories predict that the effects of brain dysfunction will be more severe the earlier the age of onset. According to Hebb (Boll & Barth, 1981), for example, brain damage most affects the kind of current problem-solving ability (Type A intelligence) upon which children rely, whereas the stored information (Type B intelligence) which adults tend to use



in their day-to-day functioning is less affected. In terms of Luria's theory (Golden, 1981), with earlier age of onset the primary functional systems of the brain are disrupted, thereby altering the basic abilities upon which more complex skills are built. This theory, like Hebb's, would predict a greater overall level of cognitive impairment with an early onset of brain dysfunction.

The findings in the empirical literature are equivocal in their support of these theories. McFie (1961), for example, failed to find a trend associating Full-scale IQ on the Wechsler intelligence scale with age of onset in a heterogeneous sample of brain-damaged children. Klove and Matthews (1974) found a linear relationship between Full-scale IQ and age of onset for a group of adults with major motor seizures of known etiology but not for a group with major motor seizures of unknown etiology or a brain-damaged group without epilepsy. On the basis of these findings, it is difficult to predict the effects of age of onset on the level of intelligence test performance in children with psychomotor seizures of unknown etiology.

#### Lateralization of Epileptiform Activity in the Brain.

Stores (1978) has reviewed the results of a series of preliminary studies aimed at identifying those epileptic children attending ordinary schools who are at greatest risk

of behavioral complications. A major finding from these studies was an association between a persistent left temporal spike discharge and a number of problems, including reading retardation, inattentiveness, emotional dependence, and overactivity. In contrast, children with a right temporal lobe spike discharge were frequently found to be no different from non-epileptic children. Since brain dysfunction in children has been found in association with behavior problems (Rutter, 1977, 1981) and a lower Wechsler Full-scale IQ (Boll, 1974; Reitan & Klove, 1965; Reitan, 1974), one might predict that these different types of disturbed behavior in left temporal lobe epileptic children will be found in association with a lower level of intellectual functioning relative to that of children with right temporal lobe epilepsy.

### Hypotheses

It is hypothesized that at least some of the seizure-related variables selected on the basis of the theoretical and empirical neuropsychological literature (seizure type, seizure frequency, number of anticonvulsants, types of EEG abnormality, age of onset, and lateralization) will prove to be significant predictors of the level of intelligence test performance in children with temporal lobe

epilepsy. On the other hand, Schwarz and Dennerll (1970) have suggested that independent indices of the severity of seizure disorders are inadequate and that a weighted series of variables is more likely to provide a workable index. It is further hypothesized, therefore, that, in the absence of a significant effect for any seizure-related variable when considered individually, the level of intelligence test performance in children with lateralized temporal lobe epilepsy will be significantly predicted by a combination of these variables.



## METHOD

### Selection and Description of the Subjects

The population of interest consisted of outpatients who had been treated for a seizure disorder by the neurology department of the Izaak Walton Killam Hospital for Children.<sup>1</sup> The sample was obtained by examining the EEG records of a consecutive series of cases in the files for the period of July 1976 to September 1981, and selecting all those which demonstrated a strictly lateralized temporal lobe spike discharge. The families of the 36 selected children were contacted and 27 of these agreed to participate in the study. One of the subjects was unwilling to cooperate with the psychological testing. The data for this subject were excluded from the analyses.

A summary description of the overall sample, and of the left and right temporal groups, is presented in Table 1. The results of the tests for differences between the left and right temporal groups on the variables of age at testing and level of education were nonsignificant. Chi-square tests for sex differences, and differences in socioeconomic status as measured by the Hollingshead Index (Note 1) were also nonsignificant. Two subjects in the left temporal group and three subjects in the right temporal group were

Table 1

Age at Testing, Education, Sex, and Socioeconomic Status of the  
Overall Sample, and Left and Right Temporal Lobe Groups

	Overall (n=26)	Left (n=12)	Right (n=14)
Age at testing (years)			
Mean	12.5	12.8	12.2
S.D.	3.3	2.6	3.8
Education (grades)			
Mean	7.1	7.5	6.3
S.D.	3.1	2.8	3.4
Sex			
Male	15	7	8
Female	11	5	6
Socioeconomic status <sup>a</sup>			
2	3	1	2
3	15	7	8
4	7	4	3
5	1	0	1

<sup>a</sup> Based on the Hollingshead two-factor index of social position

(Note 1).

left-handed. Two of the left-handed subjects in the right temporal group also had a left-handed parent, which suggests that these subjects may have been genotypic sinistrals and therefore possibly predisposed toward poorer nonverbal skills in the absence of brain dysfunction (Miller, 1972). This consideration may limit the interpretation of the results (Kershner & King, 1974).

### Intelligence Testing

The Wechsler Intelligence Scale for Children-Revised (WISC-R) was administered to the 22 subjects between the ages of 8 and 16 years, and the Wechsler Adult Intelligence Scale (WAIS) was administered to four 17-year-old subjects. The scales were administered individually to subjects in a standardized manner by trained psychometrists who were aware of the nature of the sample and the general purpose of the research, but were uninformed as to the group membership (left- or right-hemisphere EEG abnormality) of the subjects.

### Neurological Examination

The EEG records of the temporal lobe epileptic children were examined by a certified electroencephalographer for evidence of a unilateral interictal spike focus

restricted to the temporal lobe. Patients were excluded whose records demonstrated secondary bilateral synchrony, or a focal discharge which extended beyond the temporal lobe or occurred independently in the opposite temporal lobe. The EEG records of selected patients were further classified as to whether they demonstrated a spike discharge and focal slowing, or a spike discharge alone. The number of EEG recordings conducted per subject ranged from one to seven.

A standard neurological examination was conducted which included testing for peripheral sensory-motor deficits and neurological "soft signs". Four left temporal and six right temporal subjects had abnormal findings on the neurological examination. One left temporal subject had a right visual field defect (hemianopsia) and two right temporal subjects had left visual field defects (hemianopsia, quadrantanopsia). The findings on the neurological examination therefore supported the EEG findings for the lateralization of cerebral dysfunction in these children.

A neurological history was conducted which involved the collection of data on a number of seizure-related variables including seizure type, seizure frequency, number of anticonvulsants, types of EEG abnormality, age of onset, and duration of the seizure disorder-(Table 2). Chi-square tests for differences between the left and right temporal

Table 2

Seizure History Information for the Overall Sample,  
and Left and Right Temporal Lobe Groups

	Overall (n=26)	Left (n=12)	Right (n=14)
Seizure type <sup>a</sup>			
psychomotor alone	12	7	5
psychomotor plus major motor	14	5	9
Seizure frequency <sup>b</sup>			
0	17	9	8
1 to 10	4	0	4
11 to 50	3	2	1
more than 50	2	1	1
Number of anticonvulsants			
0	5	3	2
1	15	6	9
2	5	2	3
3	1	1	0
Type of EEG abnormality			
spike alone	12	7	5
spike plus slowing	14	5	9
Age of onset (years)			
mean	8.6	9.1	8.2
S.D.	3.8	3.2	4.3
Duration of disorder (years)			
mean	3.9	3.7	4.0
S.D.	3.3	2.4	4.0

<sup>a</sup> For one left and two right temporal subjects it was not certain whether a generalized major motor seizure had occurred. These subjects were classified as not having had a major motor seizure.

<sup>b</sup> Based on range estimates provided by the parents and child for the year preceding psychological examination.



groups on these variables were nonsignificant. These findings are not conclusive, however, since in each case there were cells with expected frequencies of less than 5.

### Data Analyses

To test for a main effect of the seizure-related variables on Full-scale IQ when considered individually, subjects were classified dichotomously according to seizure type (psychomotor alone or psychomotor plus major motor), seizure frequency (none or at least one seizure in the year of testing), number of anticonvulsants prescribed (one or more than one type), types of EEG abnormality (spike discharge alone or spike plus focal slowing), age of onset of seizures (before or after nine years),<sup>2</sup> and lateralization of spike discharge (left or right temporal lobe). Mean Full-scale IQ scores were determined for the six pairs of groups and differences between these means were tested for using  $t^o$  tests for independent samples.

Stepwise multiple regression analyses were then conducted to arrive at the best weighted combination of variables for predicting Full-scale IQ in this sample. Continuous data were entered for number of anticonvulsants and age of onset, and dichotomous data were entered for seizure type, types of EEG abnormality, and lateralization. The coding of seizure frequency was problematic since the data for this variable were collected in terms of range estimates (0, 1 to 10, 11 to 50, more than 50 seizures in the year of testing). It was thought that the

dichotomization of this variable might result in a loss of potentially useful information. On the other hand, the arbitrary selection of point estimates might result in the addition of inaccurate information. To assess the effects of coding the data for seizure frequency either dichotomously or in terms of point estimates, three separate regression analyses were conducted. For the first analysis, the data were coded dichotomously: (0) if the subject had not had a seizure in the year of testing, (1) if the subject had one or more seizures in the year of testing. For the second analysis, the minimum points of each range were used: (0) if the subject had no seizures, (1) if the subject had 1 to 10 seizures, (11) if the subject had 11 to 50 seizures, and (50) if the subject had more than 50 seizures in the year of testing. For the third analysis it was reasoned that, since the sample was skewed toward a milder degree of impairment on many of the variables, the most representative data would be a point estimate between the minimum and midpoint for the ranges with lower and upper limits. The data for this third analysis were coded: (0) if the subject had no seizures, (4) if the subject had 1 to 10 seizures, (20) if the subject had 11 to 50 seizures, and (50) if the subject had more than 50 seizures in the year of testing. The data for the other five seizure-related variables were coded in the same way for all three regression analyses.

Computer analyses of the Full-scale IQ scores and the data for the six predictor variables were conducted by means of the SPSS multiple regression subprogram (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975). The results of the regression analyses were evaluated in terms of the overall accuracy of the prediction equation as reflected by the square of the multiple correlation,  $R^2$  (a measure of the proportion of variation in the criterion explained by the variables included in the regression equation) and by the relative contributions of the individual variables as measured by the standardized regression coefficients, or beta weights.

### RESULTS

Results of the  $t$  tests (Table 3) indicate a significant effect for number of anticonvulsants ( $t(24)=2.09, p<.05$ ). The tests for seizure type, seizure frequency, types of EEG abnormality, age of onset of the seizure disorder, and lateralization of the spike discharge were not significant. The differences between the means were in the expected direction for three variables: seizure frequency, number of anticonvulsants, and age of onset. Specifically, the mean Full-scale IQ scores were higher for children who had not had a seizure in the year of testing, who had been prescribed only one type of anticonvulsant, and for whom the age of onset of seizures was later (after nine years). For the remaining three variables (type of seizures, types of EEG abnormality, and lateralization of spike discharge) the differences between the means were in a direction opposite to that predicted. Specifically, the mean Full-scale IQ scores were higher for children with psychomotor and major motor seizures, spike discharges and focal slowing, and right hemisphere dysfunction.

Results from the three regression analyses (with seizure frequency coded dichotomously, or in terms of minimum or low mid-range point estimates) were essentially the same in terms of the overall accuracy of the prediction

Table 3

Means and Standard Deviations of Full-Scale IQ Scores  
for the Seizure Variable Groups

	Full-Scale IQ		
	Mean	S.D.	<u>n</u>
Seizure type			
psychomotor alone	99.5	12.3	12
psychomotor plus major motor	103.1	14.5	14
Seizure frequency			
none in the year of testing	103.8	13.6	16
one or more in the year of testing	96.4	12.4	10
Number of anitconvulsants.			
zero to one	104.1	* 13.8	19
more than one	91.8	6.6	7
Types of EEG abnormality			
spike alone	93.7	27.3	18
spike plus slowing	105.6	11.6	8
Age of onset			
before nine years	100.6	11.2	11
after nine years	106.3	13.2	11
Lateralization of brain dysfunction			
left	101.5	15.3	12
right	101.1	12.2	14

\*  $p < .05$

equation ( $R^2$ ) and the relative contributions of the individual predictor variables ( $B$ -values). A correlation matrix of seizure variables with Full-scale IQ is presented in Table 4. Results from the third regression analysis, with seizure frequency coded in terms of low mid-range point-estimates, is presented in Table 5.

The stepwise multiple regression procedure resulted in a nonsignificant regression equation. Only 38% of the variation in the Full-scale IQ scores of the present sample of temporal lobe epileptic children was explained by the five seizure variables (seizure frequency, number of anticonvulsants, types of EEG abnormality, age of onset, and lateralization) included in the regression equation. Seizure type did not meet the statistical criteria (Nie et al., 1975) for entry into the equation (the  $F$ -ratio computed in the test of significance for its regression coefficient and the tolerance, or proportion of variance in seizure type not explained by the variables already in the equation, failed to exceed the default values of  $F=.01$  and  $T=.001$ ).

The relative contributions of the individual seizure variables to the explained variation in Full-scale IQ were nonsignificant in each case except for number of anticonvulsants. This variable had the highest simple correlation with Full-scale IQ ( $r=-.53$ ), and accounted for 28% of the variation in the Full-scale IQ scores.

Table 4

## Correlation Matrix of Seizure Variables with Full-scale IQ

Seizure type <sup>a</sup>	-.15					
Seizure frequency <sup>b</sup>	-.35	-.07				
Number of anticonvulsants <sup>c</sup>	-.53	-.22	.74			
Types of EEG abnormality <sup>d</sup>	.22	-.05	-.18	.04		
Age of onset <sup>e</sup>	.10	.16	-.19	.07	.23	
Lateralization <sup>f</sup>	.02	-.23	.05	.01	-.12	.12
	Full-scale IQ	Seizure type	Seizure frequency	Types of EEG abnormality	Age of onset	Lateralization

<sup>a</sup> Coded 0 for psychomotor seizures alone, 1 for psychomotor and major motor seizures

<sup>b</sup> Coded 0 for no seizure, 1 for one or more seizures in year of testing

<sup>c</sup> Coded 0, 1, 2, or 3 anticonvulsants

<sup>d</sup> Coded 0 for spike discharge, 1 for spike discharge and slowing

<sup>f</sup> Coded 0 for right temporal spike, 1 for left temporal spike



Table 5

Regression Summary Table  
Dependent Variable WISC-R Full-Scale IQ

SOURCE	<u>df</u>	<u>SS</u>	<u>F</u>	<u>B-value</u>	<u>R<sup>2</sup></u>
Regression	5	1707.93	2.44		.38
Number of anticonvulsants	1	1249.62	9.20	-.78 **	
Seizure frequency	1	536.31	3.24	.31	
Types of EEG abnormality	1	219.24	1.23	.28	
Age of onset	1	43.45	.23	.14	
Lateralization	1	1.20	.01	.02	
Residual	20	2803.19			
Total	25	4511.12			

\*\* p<.01


## DISCUSSION

### Regression Equation

The best weighted linear combination of the six seizure-related variables accounted for approximately one-third of the variability in the Full-scale IQ scores of the present sample of temporal lobe epileptic children. This indicates that approximately two-thirds of the variability in the level of intelligence test performance in these children is explained by factors other than the severity of their seizure history, as measured in this study. In view of the findings in the literature for an effect of the seizure-related variables on the level of cognitive functioning in children or adults with epilepsy (Dikmen & Matthews, 1977; Dodrill, 1981; Klove & Matthews, 1974; Stores, 1978 ), the absence of a significant relationship between Full-scale IQ and five of the six variables, when considered individually or in combination, is not expected.

There are a number of possible explanations for the absence of a significant effect for most of the seizure variables on level of intelligence test performance in the present sample. One explanation is the small sample size which would make the data sensitive to between-group

differences in premorbid Full-scale IQ. Secondly, one might expect that the most severely impaired children have received some type of remedial help, thereby reducing differences between children with mild and severe seizure histories. A third explanation is that the sampled range in severity of seizure history was very restricted. Studies in which significant effects have been found for some of the seizure variables which were under investigation in the present study have used wider ranges for these variables. In a study of adults with epilepsy (Klove & Matthews, 1974), age of onset ranged from less than one year to fifty years. In the present study, age of onset ranged from one to sixteen years. In another study of adults with epilepsy (Dikmen & Matthews, 1977), seizure frequency ranged from less than one seizure per year to more than one seizure per day. In the present study, only 35% of the sample (nine subjects) had more than one seizure in the year of testing. It appears, then, that only the mild end of the continuum of neurological impairment was sampled in the present study. It is difficult to predict variability in level of cognitive impairment in such a homogeneous group since such variability is minimal in the predictor measures.



### Individual Predictors


Number of Anticonvulsants. When the seizure variables are considered individually, the number of anticonvulsants required for effective seizure control appears to be the only significant predictor of Full-scale IQ in temporal lobe epileptic children, at least for the present sample. It is difficult to determine whether this effect for number of anticonvulsants reflects a more severe seizure disorder or an effect for type of anticonvulsant in the children prescribed more than one type of anticonvulsant. The fact that an association has been found between phenytoin and behavior problems (Stores, 1978) would suggest an effect for type of anticonvulsant, since six of the seven children prescribed more than one type of anticonvulsant had been prescribed phenytoin, compared with only one of the nineteen prescribed zero to one type of anticonvulsant. On the other hand, only three children in the sample were judged by the neurologist and parents to be suffering from either medical or behavioral effects of the medication. This would suggest that the lower level of intellectual functioning in the children prescribed more than one type of anticonvulsant is due to the recalcitrance of their seizures.

Seizure Type. The prediction that children with both psychomotor and major motor seizures would obtain a lower mean Full-scale IQ than the children with psychomotor seizures alone was not supported by the results of the present study. The absence of a significant relationship between seizure type and Full-scale IQ contrasts with the finding of greater neuropsychological impairment, as measured by the Halstead Impairment Index, in adults with mixed (major motor and psychomotor) seizures (Klove & Matthews, 1974). It may be that the adults with mixed seizures in this study had a larger proportion of the seizure activity represented by major motor seizures. In the present study, the subjects classified as having both types of seizures had generally experienced only one major motor seizure. It is possible that a significantly lower mean Full-scale IQ would be found in children with a higher proportion of major motor to psychomotor seizures. On the other hand, the nonsignificant findings of the present study may reflect the absence of a relationship in children between seizure type and level of intelligence test performance.

Seizure Frequency. Differences in mean Full-scale IQ between children with no recent seizures and those with one or more seizures in the year of testing were in the expected

direction, but were not significant. The absence of a significant relationship between seizure frequency and Full-scale IQ in the present sample of temporal lobe epileptic children contrasts with the finding of a significant effect for seizure frequency in adults with major motor seizures (Dikmen & Matthews, 1977). The discrepancy between the results of these two studies may reflect differences in the effects of seizure frequency on intellectual functioning in children and adults.

Alternatively, it may reflect limitations in the accuracy of information which can be collected for this variable in children with psychomotor seizures and strictly lateralized temporal lobe spike discharges. In the adult study, measures were obtained which reflected the relative seizure frequency of the subject over the entire span of the seizure disorder. This precision was made possible by restricting the data pool to subjects with the most complete and detailed medical histories. The small subject pool available for the present study precluded such selection. Moreover, the nature of the predominant type of seizure experienced by subjects in the present study made it difficult to obtain accurate estimates of frequency. Psychomotor seizures frequently involve subtle trancelike states rather than overt symptomatology and it is therefore difficult for the parents to identify, and the child to



report, when a seizure has occurred. If the problems inherent in the collection and coding of data for this variable could be avoided, it is reasonable to expect that seizure frequency would be a significant predictor of level of intellectual impairment in temporal lobe epileptic children. As coded in the present study, however, seizure frequency was essentially another measure of the controllability of seizures in addition to number of anticonvulsants. This is evidenced by the strong correlation ( $r=.74$ ) between seizure frequency and number of anticonvulsants (see Table 4). It is not surprising, therefore, that this variable added little to the explained variability in Full-scale IQ scores already contributed by number of anticonvulsants.

Types of EEG Abnormality. No relationship was found between the EEG variables considered in the present study and Full-scale IQ in the temporal lobe epileptic children. In adults with epilepsy, slow wave EEG abnormalities have been found to be more effective than spike discharges in differentiating neuropsychological test performances, while the simultaneous use of both EEG variables has been found to maximize the dispersion of neuropsychological test scores (Dodrill & Wilkus, 1978). In the present study, the children with spike discharges and slowing in the EEG did

not have a significantly lower mean Full-scale IQ than those with spike discharges alone. In fact, the nonsignificant difference between the mean Full-scale IQ scores of the two groups of children was in the opposite direction. The discrepancy between the studies may reflect differences in the effects of EEG variables on cognitive functioning in children and adults. In a study which involved children with behavior and/or school problems, those with an abnormal EEG were found to perform better on average than those with a normal EEG on an extensive battery of neuropsychological tests (Tymchuk, Knights, & Hinton, 1970). This and similar findings have led Boll and Barth (1981) to conclude that, as an indicator of the presence or severity of psychological-behavioral dysfunction, the presence of EEG abnormalities has little value. This contrasts with Dodrill's (1981) claim, based on findings for adults with epilepsy, that EEG variables are likely to demonstrate the strongest relationships with performance. The present data for children with lateralized temporal lobe epilepsy would tend to support the conclusion of Boll and Barth.

Age of Onset. The absence of a significant relationship between age of onset and Full-scale IQ in the present study contrasts with findings for adults with major motor seizures of known etiology (Dikman et. al., 1977;



Klove & Matthews 1974) An effect for this variable may depend to a large degree on the range sampled for the late age of onset group. Dikmen, Matthews, and Harley (1977) found, for example, that, by extending the limit for the late onset group downward from 16 to 10 years, the differences between the early and late onset groups became much less pronounced. Similarly, Klove and Matthews (1974) found significant differences in the mean Halstead Impairment Index ratings between the early childhood (0 to 5 years) and adult (17 to 50 years) age of onset groups, and between the late childhood (6 to 16 years) and adult age of onset groups, but not between the early and late childhood age of onset groups. These findings suggest that the differences in level of cognitive impairment found between brain-damaged children and adults may not reflect a gradual decrease in the effects of brain damage with an increase in age of onset, but rather a more abrupt change in the effects of brain damage in the early adult years.

#### Lateralization of the Temporal Lobe Spike Discharge.

No relationship was found between the lateralization of spike discharge and Full-scale IQ in the present sample of temporal lobe epileptic children. An increased incidence of behavioral disturbances (inattentiveness, emotional dependence, overactivity) has been reported for temporal

lobe epileptic children with left temporal lobe spike discharges (Stores, 1978). Since a lower level of intellectual functioning has been found in association with behavior problems in children with brain dysfunction (Rutter, 1977, 1981), it was predicted that the children with left temporal lobe spike discharges in the present sample would demonstrate a significantly lower mean Full-scale IQ than the children with right temporal lobe spike discharges. This prediction was not supported, although findings reported for the collaborative research project at the IWK Hospital (Gates, Ferguson, Ronen, MacDonald, Camfield, & Camfield, Note 2) indicate that there was a nonsignificant trend toward a higher incidence of socio-emotional maladjustment (as measured by the Personality Inventory for Children) in the children with left temporal lobe spike discharges.

PART TWO. PREDICTION OF PATTERN OF INTELLIGENCE TEST  
PERFORMANCE IN CHILDREN WITH LATERALIZED TEMPORAL  
LOBE EPILEPSY.

Selection of Predictors

On the basis of the theoretical and empirical neuropsychological literature, three neurological variables have been identified for the present investigation as possible predictors of the pattern of intelligence test performance in children with temporal lobe epilepsy which maximally involves one side of the brain. These three neurological variables are the lateralization, age of onset, and the severity of the brain dysfunction.

Lateralization of Brain Dysfunction. A frequent finding in the adult neuropsychological literature has been a pattern of performance on the Wechsler-Bellevue Intelligence Scale, Form 1 (WB-1) and the Wechsler Adult Intelligence Scale (WAIS) associated with lateralized brain damage. Specifically, patients with left hemisphere damage have been found to have lower Verbal than Performance scale scores while patients with right hemisphere damage have been found to have lower Performance than Verbal scale scores. These patterns have been found in adults with major destructive lesions for whom the lateralizing criteria have

included surgery (Reitan, 1955), the EEG (Klove, 1959), and lateralized motor deficits (Reed & Reitan, 1963). They have also been found in adults with temporal lobe epilepsy for whom the lateralizing criteria were unilateral psychomotor seizures and temporal lobe EEG abnormalities (Dennerll, 1964). While contradictory findings have been reported (Smith, 1971; Snow, Dinkin, Sheese, & Ridgley, Note 3), the results from a majority of the studies in the adult neuropsychological literature suggest that, in right-handed adults, the brain is functionally lateralized with the left hemisphere specialized for the processing of verbal information and the right hemisphere specialized for the processing of visuospatial information.

In the child neuropsychological literature, findings from studies of the cognitive effects of unilateral cerebral dysfunction have been much less consistent. While the same patterns found in unilaterally brain-damaged adults have been reported for children with lateralized EEG abnormalities (Annett et al., 1961; Fedio & Mirsky, 1969) and lateralized motor deficits (Kershner & King, 1974), patterns opposite to these have also been reported. A lower Performance than Verbal IQ score on the Wechsler Intelligence Scale for Children (WISC), for example, has frequently been reported for children with left-hemisphere brain damage and right lateralized motor deficits (Kohn &

Dennis, 1974; Reed & Reitan, 1967; Woods, 1980), while a lower Verbal than Performance IQ score has been reported for children with right-hemisphere EEG abnormalities (Pennington et al., 1965). These inconsistencies in the reported effects of unilateral brain dysfunction in children are found across studies which have involved similar neurological populations and similar criteria for the lateralization of cerebral pathology.

There is evidence from studies of neurologically intact children that the young brain is functionally lateralized in a manner similar to that the adult brain as early as three years and possibly infancy (Ingram, 1975; Molfese et al., 1975). Patterns of impairment similar to those found in adults, specifically, lower Verbal IQ with left-hemisphere damage and lower Performance IQ with right-hemisphere damage, would therefore be expected to result from unilateral brain dysfunction in children. Findings in the child neuropsychological literature of a lower Performance IQ in association with left-hemisphere dysfunction and lower Verbal IQ in association with right-hemisphere dysfunction suggest that, in some children, an alternative mechanism for recovery results in patterns of impairment opposite to those predicted by the lateralization of the brain damage.

One mechanism by which recovery of function from

unilateral brain damage may occur is through the restoration of function to temporarily inactive cortical areas. In partially-recovered patients for whom this mode of recovery is in effect, the functions for which the injured hemisphere is specialized, or dominant, would continue to be mediated through the damaged tissue. In these individuals, one would predict the occurrence of expected patterns of impairment (verbal deficits in association with left-hemisphere damage and visuospatial deficits in association with right-hemisphere damage). Another mechanism by which recovery from unilateral brain damage may occur is through the interhemispheric "transfer" of function, or the compensatory assumption of the impaired function by homologous areas in the intact hemisphere. Evidence that this mode of recovery does indeed occur comes from a study which involved young adults who had suffered early lateralized brain injury and had later undergone decortication of the left or right hemisphere for the relief of seizures (Kohn & Dennis, 1974). When compared on the Wechsler subscales, the two groups were not found to differ significantly in Verbal and Performance IQ, indicating that those abilities which would have been mediated by the missing hemisphere had become mediated by the intact hemisphere.

There is evidence to suggest that, when

interhemispheric transfer occurs as a result of early lateralized brain injury, the functions of the damaged hemisphere are recovered at the expense of the functions mediated by the intact hemisphere. Lansdell (1969), for example, found that adults who had developed right hemisphere speech (evidenced by sodium amytal testing) as a result of early left hemisphere injury, obtained higher verbal than nonverbal factor scores on the Wechsler-Bellevue Intelligence Scale. Annett et al. (1961) found that children who had suffered early right hemisphere damage and had developed mixed handedness (from which these investigators inferred an exchange of functions between the hemispheres), tended to obtain a higher Performance IQ than Verbal IQ on the WISC. In individuals for whom an interhemispheric mode of recovery is in effect, then, one would expect to find reversed patterns of impairment (visuospatial deficits in association with left-hemisphere damage, verbal deficits in association with right-hemisphere damage).

Different theories have been proposed to explain why the functions of the intact hemisphere might suffer as a result of interhemispheric transfer. Moscovitch (1976) has proposed that when language develops in the right hemisphere as a result of early hemisphere injury, it takes over some structures that would normally mediate nonverbal function,

thereby lowering performance on nonverbal tasks. This explanation presupposes that the acquisition of language precedes the acquisition of visuospatial skills. Annett et al. (1971) have proposed, instead, that the acquisition of visuospatial skills has primacy in time and survival value. Consequently, when visuospatial skills develop in the left hemisphere as a result of early right hemisphere injury, linguistic functioning becomes mediated by the damaged hemisphere, thereby lowering performance on verbal tasks. According to this theory, language and visuospatial abilities cannot both be developed in a single hemisphere.

While the phenomenon of recovery through interhemispheric transfer may not account for reversed patterns of impairment in all cases, an understanding of why this mode of recovery occurs in some children but not others, and more frequently in children than adults, may increase the percentage of accurate predictions made regarding the type of deficits which will ultimately be seen in the child with damage maximally involving one side of the brain.



Age of Onset of Brain Dysfunction

There are a number of theories which would suggest that lateralized brain damage which occurs at a later age is less likely to result in reversed patterns of impairment. One theory which addresses itself specifically to age of onset is concerned with the cognitive development of the child. Witelson (1976), for example, has suggested that interhemisphere plasticity may decrease in stages, closely linked to the emergence of specific mental abilities at different stages of development. According to this theory, as a cognitive function becomes part of the child's repertoire it becomes mediated predominantly by the left hemisphere if it is mainly dependent on a sequential, analytic mode of processing, and predominantly by the right hemisphere if it is mainly dependent on a parallel, holistic mode of processing. Witelson has proposed that, with the acquisition of cognitive skills, each hemisphere becomes increasingly committed to its own unique mode of information processing and increasingly unable to assume the mode necessary to mediate functions which are characteristic of the opposite hemisphere. Evidence for this theory comes from a study of adults with right hemisphere speech (Lansdell, 1969). Subjects who had suffered early left hemisphere injury (before age 5) obtained a higher Verbal

IQ, whereas those who had suffered left hemisphere injury at a later age (after age 5) obtained a lower Verbal IQ.

Findings in the child neuropsychological literature are equivocal, however, in their support of an association between the age of onset of brain damage and the pattern of cognitive impairment. There are a number of studies which support such an association. For example, two studies in which a reversed pattern of impairment (a lower Performance IQ in association with left hemisphere damage) was found, involved children with an early (under 3 years) age of onset of brain damage (Kohn & Dennis, 1974; Reed & Reitan, 1969), while a study (Fedio & Mirsky, 1969) in which the predicted patterns of impairment were found (lower Verbal IQ in association with left hemisphere damage, lower Performance IQ in association with right hemisphere damage) involved children with a later age of onset (ranging from 3 to 10 years). There are findings, however, which contradict the view that interhemispheric plasticity decreases with an increase in age of onset. A study (Woods, 1980) in which a reversed pattern of impairment was found (again, a lower Performance IQ in association with left hemisphere damage) involved a group of children with a later age of onset (ranging from 1 to 15 years), while a study (Kershner & King, 1974) in which the predicted patterns of impairment were found involved children with an early age of onset

(under 2 years).

x The findings from the child neuropsychological literature suggest that a combination of the age of onset and lateralization of the brain dysfunction may be a better predictor of pattern of impairment than lateralization alone, but still insufficient to make reliable predictions in all cases.

### Severity of Brain Dysfunction

Theories of the mechanism underlying recovery through interhemispheric transfer, as well as findings from the empirical neuropsychological literature, suggest a third variable which may be useful in predicting the pattern of intelligence test performance in children with lateralized temporal lobe epilepsy. The theories of Moscovitch (1976) and Kinsbourne (1974, 1981) explain how the severity of brain dysfunction may predict the pattern of cognitive impairment.

Moscovitch (1976) has proposed that the right hemisphere has linguistic capacities which, in the intact brain, are suppressed by the left hemisphere. According to this theory, the phenomenon of interhemispheric "transfer" following early left hemisphere injury involves the release of right hemisphere language from left hemisphere control. Language-related disturbances occur, Moscovitch has suggested when the damaged left hemisphere continues to suppress the verbal activity of the right hemisphere.

Kinsbourne (1974, 1981) has adopted this "release from inhibition model" of interhemispheric transfer and has developed it further to explain why a damaged left hemisphere continues to exert its control in some instances but not in others. According to this theory, the fact that

focal lesions within a lobe or hemisphere result in deficits that are not observed after loss of the whole lobe or after hemispherectomy, provides a significant clue to the mechanism of compensation. Kinsbourne (1976) writes:

The two hemispheres seem to be in mutually inhibitory competition. Damage to one will only release the other for purposes of compensation if the lesion is severe enough to disinhibit the other side of the brain. In left-hemispherectomized patients, the right hemisphere can compensate because it is totally free from competitive inhibition from the other side. But if the early left-sided damage is mild, it will suffice to impair the left hemisphere's language potential, but it will not release the right hemisphere for compensatory purposes (p. 205).

According to this theory, the extent of recovery through interhemispheric transfer is a function of the severity of the damage in the injured hemisphere.

Findings in the child neuropsychological literature generally support the view that the possibility of recovery through interhemispheric transfer increases with an increase in the severity of the brain damage. Three studies in which the expected patterns of impairment (lower Verbal IQ with left hemisphere damage, lower Performance IQ with right hemisphere damage) were found, involved mildly impaired

children. Two of these studies involved children with lateralized epileptiform discharges (Annett et al., 1961; Fedio & Mirsky, 1969), while the third involved children with mild lateralized motor deficits (Kershner & King, 1974). Three studies where reversed patterns of impairment (lower Performance IQ in association with left hemisphere damage) were found, involved more severely impaired children. Two of these studies involved children with severe lateralized motor deficits (Reed & Reitan, 1969; Woods, 1980), while the third involved hemispherectomized children (Kohn & Dennis, 1974).

The Moscovitch-Kinsbourne theory of interhemispheric transfer is also consistent with the view that the possibility of recovery through this mode decreases with an increase in age of onset. Myelination of the corpus callosum is partially complete by about six years of age and fully complete around age ten (Yakovlev & Lecours, 1967). To the extent that this process may facilitate interhemisphere inhibition, increasingly severe damage may be required at a later age of onset before the compensatory ability of the intact hemisphere is released from inhibition by the damaged hemisphere. According to the Moscovitch-Kinsbourne theory of interhemispheric transfer, then, the pattern of impairment in a child with lateralized temporal lobe epilepsy might be most reliably predicted by

knowledge of the lateralization, age of onset, and severity of the brain dysfunction in the child.

### Hypotheses

Consistent with the findings for other samples of mildly-impaired children with lateralized brain dysfunction (Annett et al., 1961; Fedio & Mirsky, 1969; Kershner & King, 1974), it was hypothesized that, on a group basis, children with lateralized temporal lobe epilepsy of unknown etiology would show the expected patterns of impairment (specifically, a lower mean Verbal IQ for the left lateralized group and lower mean Performance IQ for the right lateralized group). It was further hypothesized according to the evidence discussed above that, on an individual basis, lateralization alone may not be the best predictor of the pattern of cognitive impairment in these children, but rather the interactions between age of onset and lateralization, and severity and lateralization, may be better predictors than lateralization alone. Finally, it was hypothesized that the interaction between the lateralization, age of onset, and severity of the brain dysfunction would be the best predictor of the pattern of intelligence test performance in children with temporal lobe epilepsy maximally involving one side of the brain.



## METHOD

Subscale IQ and subtest data used in this second part of the study were collected during the same administration of intelligence tests which provided the Full-scale IQ data for the first part of the study. The same subject pool was used in both parts of the study.

### Selection of Measures of Severity

In children with temporal lobe epilepsy of unknown etiology, it is difficult to measure directly the severity of cerebral pathology. It was thought, however, that this might be inferred from various aspects of their seizure history which are more accessible to measurement. Since the Wechsler Full-scale IQ score has been found to reliably differentiate between groups of brain-damaged and neurologically intact children (Reed et al., 1965; Boll, 1974; Reitan, 1974), the results of the regression analyses in the first part of the study, indicating the ability of the seizure-related variables to predict Full-scale IQ, were used to select the best measure of the severity of cerebral pathology in the present sample of temporal lobe epileptic children. Of the six variables which were evaluated as predictors of level of intelligence in the first part of the

study, only the number of anticonvulsants required to control seizures was found to be significantly related to Full-scale IQ. It was therefore selected as a measure of the severity of brain dysfunction for the second part of the study.

### Data Analyses

Chi-square statistics were used to test for a relationship between the pattern of intelligence test performance and the lateralization, age of onset, and severity (number of anticonvulsants required to control seizures) of brain dysfunction. Patterns of performance were classified as expected (lower Verbal IQ with left spike discharge, lower Performance IQ with right spike discharge) or reversed (lower Performance IQ with left spike discharge, lower Verbal IQ with right spike discharge), and frequencies were determined for the occurrence of each pattern in interaction with each of the dichotomously classified seizure-related variables (left or right spike discharge, early or late age of onset, zero to one or more than one anticonvulsant). In addition, differences between the left and right temporal groups in their mean subscale IQ and subtest scores were tested for by means of independent t tests.

A stepwise discriminant analysis was conducted to determine the ability of the three seizure-related variables to differentiate between the children who obtained a lower Verbal IQ score and those who obtained a lower Performance IQ score. As with stepwise regression analysis, stepwise discriminant analysis indicates the relative usefulness of

the discriminating variables through the order of entry of variables into the discriminant function. In addition, this procedure provides probabilities of group membership for each subject as well as an overall percentage of correct classifications, thereby making it particularly well suited for clinical purposes.

Rao's  $V$ , a generalized distance measure, was used as the stepwise selection criterion. The variable selected at each step of the analysis was the one which contributed the largest increase in  $V$ , or greatest overall separation of the groups, when added to the previously selected variables. Subjects with lower Verbal IQ than Performance IQ were arbitrarily coded one (1), and subjects with lower Performance IQ than Verbal IQ were coded zero (0). In no case were Verbal IQ and Performance IQ equal. Continuous data were entered for age of onset and severity (number of anticonvulsants), and dichotomous data were entered for lateralization of spike discharge. The hypothesized interactions between these seizure-related variables were tested by multiplying lateralization with the other variables, and entering their products as new variables. Lateralization was entered alone, and in interactions with age of onset alone, number of anticonvulsants alone, and both age of onset and number of anticonvulsants. This resulted in a total of four discriminating variables: one

single variable (lateralization), two two-way interactions (lateralization and age of onset, lateralization and number of anticonvulsants), and one three-way interaction (lateralization, age of onset, and number of anticonvulsants).

Computer analyses on the pattern scores and the data for the discriminating variables were conducted by means of the SPSS discriminant analysis subprogram (Nie et al., 1975). The discriminant function was evaluated in terms of the Wilk's lambda (an inverse measure of the discriminating power in the original variables which has not yet been removed by the discriminant function), the canonical correlation (a measure of association between the discriminant function and the variables which define group membership), and the overall percentage of correct classifications. The individual discriminating variables were evaluated in terms of their order of entry into the discriminant function.

## RESULTS

Differences between the left and right temporal groups in mean subscale IQ and subtest scores were not statistically significant (Table 6). However, differences between the means were in the expected direction, with the exception of one subtest. Verbal IQ and all of the Verbal subtest scores were lower for the left temporal group, while Performance IQ and all of the Performance subtest scores except Coding were lower for the right temporal group.

Results of chi-square tests of association between lateralization, age of onset, and severity (number of anticonvulsants), and the pattern of intelligence test performance are presented in Table 7. The chi-square test of association between lateralization of brain dysfunction and pattern of intelligence test performance was not significant ( $\chi^2(1) = .814$ ,  $p = .367$ ). The cell frequencies for the left temporal group, however, were in the expected direction, with nine children obtaining lower Verbal IQ scores and only three obtaining lower Performance IQ scores. For the right temporal group, the cell frequencies were balanced, with seven children obtaining lower Verbal IQ scores and seven obtaining lower Performance IQ scores.

The test of association between age of onset and pattern of intelligence test performance resulted in a

Table 6

Means and Standard Deviations of Verbal and Performance IQ  
and Subtest Scores for Left and Right Temporal Groups

	Left (n=12)	Right (n=14)	Difference
Verbal IQ	100.3 (19.4)	101.9 (11.6)	-1.7
Performance IQ	105.8 (16.3)	100.0 (14.1)	+5.8
Information	48.3 (10.6)	48.4 ( 9.8)	-0.1
Comprehension	47.2 ( 9.5)	48.6 ( 9.3)	-1.4
Arithmetic	48.0 ( 7.8)	49.1 ( 5.3)	-1.1
Similarities	50.8 ( 8.1)	55.4 (10.5)	-4.6
Vocabulary	48.7 (10.1)	50.4 ( 8.6)	-1.7
Digit Span	43.3 ( 5.7)	47.3 ( 9.8)	-4.0
Picture Completion	54.3 ( 7.7)	51.0 (10.1)	+3.3
Picture Arrangement	51.6 (11.3)	51.2 (10.9)	+0.4
Block Design	56.1 ( 8.6)	51.5 ( 7.0)	+4.6
Object Assembly	55.2 (14.1)	47.6 (10.9)	+7.6
Coding	46.7 (13.1)	47.7 ( 9.7)	-1.0
Mazes <sup>a</sup>	55.1 (10.8)	54.3 ( 7.6)	+0.8

<sup>a</sup> Nineteen subjects (ten in the left temporal group, nine in the right temporal group) completed the Mazes subtest.

Table 7

Contingency Tables for Chi-square Tests of Association Between  
Pattern of Intelligence Test Performance and Seizure Variables

Lateralization	WISC-R Pattern	
	expected	reversed
left	9 (75.0)	3 (25.0)
right	7 (50.0)	7 (50.0)

Age of Onset	WISC-R Pattern	
	expected	reversed
early	6 (55.5)	5 (45.5)
late	6 (55.5)	5 (45.5)

Severity (Number of Anticonvulsants)	WISC-R Pattern	
	expected	reversed
zero to one	13 (68.4)	6 (31.6)
more than one	3 (42.9)	4 (57.1)

Note: Numbers in parentheses indicate row percentages



nonsignificant chi-square statistic ( $\chi^2(1)=0$ ,  $p=1$ ), indicating no association in this sample between age of onset and pattern of intelligence test performance. The cell frequencies for the early and late age of onset groups were approximately balanced with respect to type of pattern, with six children in each group demonstrating the expected pattern and five demonstrating a reversed pattern.

The chi-square test of association between severity (number of anticonvulsants) and pattern of intelligence test performance was not significant ( $\chi^2(1)=.539$ ,  $p=.463$ ). The cell frequencies for the mildly impaired group (zero to one anticonvulsant), however, were consistent with the Moscovitch-Kinsbourne model. Thirteen children in the mildly impaired group demonstrated expected patterns of intelligence test performance while only six children demonstrated reversed patterns. In the more severely impaired group (more than one anticonvulsant) the cell frequencies were more balanced, with three children demonstrating expected patterns of intelligence test performance and four demonstrating reversed patterns.

Of the four variables entered into the discriminant analysis (lateralization alone, lateralization in interaction with age of onset, lateralization in interaction with severity, and lateralization in interaction with age of onset and severity), lateralization alone was the only

variable included in the discriminant function. This variable, however, produced a low degree of separation between the criterion groups as indicated by the nonsignificant Wilks' lambda (.934,  $p=.207$ ) and Rao's  $V$  (1.686,  $p=.194$ ), as well as the small canonical correlation (.256). Sixty-two percent of the subjects were correctly classified by lateralization of spike discharge, with three errors in classification for the left temporal group and seven errors in classification for the right temporal group. Since 16 of the 26 subjects demonstrated a lower Verbal IQ, 62% correct classifications would result from classifying all subjects as having a lower Verbal IQ. The 62% level of correct classifications arrived at in the discriminant analysis through the use of lateralization information therefore represents a chance level of accuracy.

## DISCUSSION

### Lateralization of Brain Dysfunction

The second part of this study was concerned with accounting for the large amount of variability in the pattern of impairment which has been found to result from lateralized brain dysfunction in children. It was hypothesized that, as a group, children with temporal lobe epilepsy of unknown etiology would show patterns of impairment consistent with the lateralization of the spike discharge but, on an individual basis, lateralization would not be a reliable predictor. The results of the second part of this study indicate that, as a group, the present sample of temporal lobe epileptic children demonstrated trends toward the expected patterns of impairment (Verbal IQ and Verbal subtest scores were lower for the left lateralized group, Performance IQ and five of the six Performance subtest scores were lower for the right lateralized group), but none of the group differences were significant. On an individual basis, the lateralization of spike discharge resulted in an incorrect classification of the pattern of impairment in approximately one-third of the sample.

There are a number of explanations for the poor validity of lateralization of the temporal lobe spike

discharge as a predictor of pattern of intelligence test performance in the present sample of temporal lobe epileptic children. One explanation is that the EEG may not be a reliable index of the lateralization of cerebral pathology in these children. Annett et al. (1961) have pointed out, for example, that children with epilepsy commonly show more electrical abnormality in the undamaged hemisphere than in the damaged hemisphere. Moreover, abnormal electrical activity is likely to transfer to the other hemisphere via the corpus callosum so that, even if the focus for this activity is unilateral, both hemispheres are likely to be dysfunctional.

A second explanation for the poor validity of lateralization information in predicting pattern of impairment is that, in children, the Wechsler Verbal-Performance discrepancy measure has been found to vary with a number of factors other than the lateralization of cerebral pathology. Kaufman (1967), for example, found a significant relationship between pattern of intelligence test performance in children and parental occupation. Specifically, the percentage of children of professional parents having significantly higher Verbal IQ scores was twice as large as the corresponding percentage for children of unskilled workers. Schmitt (1975) has suggested that different patterns of intelligence test performance will be

found in association with different types of emotional disturbance. This suggestion is of particular relevance to the present sample since five of the subjects had received professional counseling for emotional disturbance.

A final explanation for the lack of validity of lateralization information in predicting pattern of impairment in temporal lobe epileptic children is that other neurological factors, such as the age of onset or the severity of the cerebral pathology, may modify the effects of lateralization.

#### Age of Onset of Brain Dysfunction

On the basis of the neuropsychological literature, it was hypothesized that differences in age of onset of the seizure disorder would contribute to the variability in the pattern of impairment resulting from lateralized brain dysfunction in temporal lobe epileptic children. The results of the second part of this study indicate that the prediction of the pattern of intelligence test performance in the present sample was not improved by including the interaction between age of onset and the lateralization of the spike discharge as a predictor. The proportions of expected and reversed patterns of impairment were the same for the early and late age of onset groups. This contrasts

with the findings in the neuropsychological literature which suggest that the proportion of expected patterns of impairment increase with an increase in age of onset. For example, in a study of adults with lateralized brain damage in which the frequencies for pattern of WAIS performance were reported, 90% of the subjects were found to demonstrate expected patterns of impairment (Reitan, 1955). By contrast, in studies of children with lateralized brain damage, the reported percentages for expected patterns of impairment have ranged from 47% (Reed & Reitan, 1963) to 71% (McFie, 1961). According to the theoretical literature (Witelson, 1976; Moscovitch, 1976; Kinsbourne, 1981), the probability of expected patterns of impairment resulting from lateralized brain damage increases gradually with an increase in age of onset, as the processes of cognitive and/or neurological development gradually reduce the possibility of interhemispheric transfer. The present data are consistent, instead, with the hypothesis there is no gradual change in the effects of lateralized brain damage throughout the childhood years. As was suggested with regard to the differences in level of impairment found between brain-damaged children and adults, it may be that the early adult years represent a period of abrupt change in the pattern of cognitive impairment resulting from lateralized brain damage.

### Severity of Brain Dysfunction

Contrary to what was hypothesized, no increase in the predictability of the pattern of intelligence test performance in temporal lobe epileptic children was found as a result of including information about the severity of the seizure disorder. A number of methodological problems may account for this finding. One methodological problem was the lack of variability in the sample on the selected measures of severity. As with the prediction of Full-scale IQ, it is difficult to predict the pattern of intelligence test performance on the basis of differences in severity when such differences do not exist. The lack of variability in the severity of seizure disorder in the present sample of mildly impaired children may have resulted in a greater influence for the other factors, such as parental occupation, which have been found to affect the pattern of intelligence test performance in children.

A second methodological problem was the lack of information on the severity of cerebral pathology in the temporal lobe epileptic children at the time of onset of their disorder. The average duration between age of onset and age at testing for the sample was four years (ranging from less than one to twelve years). The severity of neurological impairment at the time of testing may not

reflect the degree of severity at age of onset of the disorder, since the child's neurological condition may improve or deteriorate over time. Insofar as the Moscovitch-Kinsbourne model of interhemispheric transfer is relevant to the proposed association between severity and pattern of impairment, age of onset would be the appropriate time at which to obtain severity measures. Even if severity information were collected at the time of onset, however, the cerebral pathology leading to the seizures may have preceded their onset by several years. This indicates the difficulty of obtaining appropriate information to test hypotheses about the effects of severity of cerebral pathology.

A final limitation in interpreting the results for severity in the present study was the questionable validity of the criteria used to assess the degree of cerebral pathology in the temporal lobe epileptic children. Problems relating to criterion information are inescapably present in any neuropsychological research endeavor (Reitan, 1966). In patients whose symptomatology would suggest brain dysfunction which cannot be detected by current neurological techniques, the use of criterion information is particularly problematic (Lenzer, 1980). In the present study, seizure-related variables were selected as indirect measures of cerebral pathology because, in subjects whose seizures



are not severe enough to justify surgery, it is impossible to obtain more direct measures of the degree of cerebral pathology. It may be, however, that there is no direct relationship between the degree of cerebral pathology and the severity of symptomatology, in which case the seizure-related variables selected as indirect measures of severity in this study may not be valid indices of the underlying neurological condition in mildly-impaired temporal lobe epileptic children.

In view of this criterion problem, it might be argued that the hypothesis of an association between severity and pattern of impairment was not effectively tested and therefore cannot be challenged. Further examination of the literature, however, suggests that, when a more direct measurement of cerebral pathology is made possible through the investigation of severely impaired subjects, an association between severity and pattern of impairment is not supported. Rasmussen and Milner (1974), for example, determined at surgery the extent of tissue damage in epileptic adults with severe left-hemisphere seizure disorders. When they correlated these findings with the results of Amytal speech tests in these patients, they found that damage in the primary speech zones at an early age was likely to result in the recovery of language functions through interhemispheric transfer whereas, even gross

lesions that spared the primary speech zones rarely seemed to result in interhemispheric transfer of speech. These findings suggest that there is no direct relationship between the severity of cerebral pathology, in terms of the extent of tissue damage, and the pattern of cognitive impairment resulting from lateralized brain lesions.

Instead, the findings of Rasmussen and Milner suggest that, at least in the case of left-hemisphere lesions, the locus rather than the severity of brain injury is a critical factor in determining the pattern of impairment. Other evidence against an association between severity and pattern of impairment is the finding of right-hemisphere speech and reversed patterns of impairment in mildly impaired adults with early left-hemisphere lesions (Lansdell, 1969). The results of the present study are consistent with this negative evidence, and suggest that the findings in the child neuropsychological literature of expected patterns of intelligence test performance in mildly impaired samples and reversed patterns of intelligence test performance in more severely impaired samples are due to factors other than an association between the severity of brain dysfunction and the pattern of cognitive impairment.

### GENERAL DISCUSSION

The purpose of this study was to identify variables which would improve the predictability of the overall level and pattern of cognitive impairment in children with temporal lobe epilepsy. The clinical utility of increased predictability is that this would enable the introduction of remedial measures before, rather than after, the child has experienced failure within the school system. The accurate prediction of the pattern of impairment that will eventually result from lateralized brain dysfunction is particularly relevant, since the pattern of deficits which is immediately apparent may change over time as a result of recovery through interhemispheric transfer of function. If it is the case that this mode of recovery occurs more often than is generally realized, as Kinsbourne (1981) has suggested, then remedial programs targeted toward the immediately apparent deficits in the child with lateralized brain dysfunction may represent an investment of time and effort in an area where spontaneous recovery is likely to occur, while the new area of deficits which may emerge as a result of interhemispheric transfer may go unnoticed.

### Prediction of Level of Intelligence Test Performance

Of the six seizure-related variables selected as predictors on the basis of the neuropsychological literature, only the number of different types of anticonvulsant required to control seizures in the temporal lobe epileptic child was found to have some association with the child's level of intellectual performance. It would seem that whether or not the child with temporal lobe epilepsy has left or right hemisphere dysfunction, an early or late age of onset of the disorder, some or no focal slowing in the EEG, some or no recent seizures, or has ever experienced a major motor seizure, has little bearing on the level of intelligence performance that the child might be expected to demonstrate.

It might be argued that the range of severity sampled on these variables was too restricted to adequately assess their value as predictors of the level of impairment in a more heterogeneous sample of neurologically impaired children. The fact that the present sample was so restricted in its range of impairment is in itself useful information about the predictability of the level of impairment in temporal lobe epileptic children. Contrary to other findings in the literature (Stores, 1978), the results of the present study suggest that, at least in the area of

cognitive functioning, the temporal lobe epileptic child is likely to perform at the same level as the child without epilepsy. Only four children in the present sample demonstrated Full-scale IQ scores which were below the Average range. Insofar as the present sample is representative of temporal lobe epileptic children in general,<sup>3</sup> the results from Part One of this study suggest that the temporal lobe epileptic child is not at particular risk in terms of overall level of cognitive impairment as measured by the Wechsler Full-scale IQ. Deficits in these children may have been more apparent, however, with neuropsychological measures. Klove (1959), for example, found that the WAIS Full-scale IQ was less sensitive than the Halstead Impairment Index to neurological impairment in adults with lateralized EEG abnormalities. While the Wechsler Full-scale IQ may not be the most sensitive measure of cognitive impairment, it was used in the present study to facilitate comparison with the extensive literature which uses Full-scale IQ to assess the effects of lateralized brain dysfunction in children and adults.

#### Prediction of Pattern of Intelligence Test Performance

None of the three variables (lateralization, age of onset, and severity of brain dysfunction) selected as

predictors of the pattern of intelligence test performance in the temporal lobe epileptic child was found to have a significant association with the relative magnitude of Verbal IQ and Performance IQ. Within the limited range of the variables sampled, it would seem that whether the temporal lobe epileptic child has a left or right temporal lobe spike discharge, an early or late age of onset, or a milder or more severe seizure disorder, has little bearing on the pattern of intelligence test performance that the child might be expected to demonstrate.

While lateralization was not found to have a significant association with pattern of intelligence test performance on an individual basis, there were trends toward an association on a group basis. It might be argued that the small sample size accounts for the lack of significant results in this study. Kershner and King (1974), however, obtained significant differences between groups of left- and right-brain-dysfunctional children with only seven subjects in each group. A difference between studies of unilaterally brain-dysfunctional children which have found significant differences (Annett et al., 1961; Fedio & Mirsky, 1969; Kershner & King, 1974) and those which have not (Reed & Reitan, 1969; Kohn & Dennis, 1974; the present study), is that the former studies compared the left- and right-brain-dysfunctional groups to a normal control group

rather than to each other. The use of a normal control group is important since the "intact" hemisphere in the unilaterally brain-dysfunctional child, and particularly in the child with epilepsy, cannot be considered normal. A second methodological consideration is the type of measure used to assess differences in patterns of cognitive impairment. In another study which involved temporal lobe epileptic children, significant differences were not found between the left and right temporal groups on the Wechsler intelligence test measures (Fedio & Mirsky, 1969). Significant differences were found, however, on measures of learning and memory which involved verbal or nonverbal material.

The lack of support for the validity of lateralization as a predictor of pattern of intelligence test performance in the present study is consistent with studies of children (Reed & Reitan, 1965; Kohn & Dennis, 1974; Woods, 1980) and adults (Smith, 1966; Snow et al., Note 3) in which expected patterns of impairment have not been found. In these latter studies, however, findings of reversed patterns of impairment involved a lower Performance IQ in association with left hemisphere dysfunction. In the present study, by contrast, the majority of reversed patterns of intelligence test performance (seven of the ten) involved a lower Verbal IQ in association with right

hemisphere dysfunction.

Findings of a lower Performance IQ in children regardless of the lateralization of brain dysfunction have led Woods and Teuber (1973) to postulate the recovery, or escape, of verbal functions at the "expense" of nonverbal functions. Similarly, the finding of a correlation between the WAIS verbal factor score and time since injury, but not between the nonverbal factor score and time since injury in adults with lateralized lesions has led Lansdell and Smith (1975) to suggest a resiliency for verbal functions and the likelihood of some permanent impairment for nonverbal functions after brain damage. On the other hand, in a number of studies of children with generalized brain damage (Reed et al., 1965; Boll, 1974; Reitan, 1974) the major deficits have been found in language-related areas. The results of the present study are consistent with these latter studies in that a majority of children (16 of the 26 subjects) demonstrated a lower Verbal than Performance IQ score.

In conclusion, insofar as the results for pattern of intelligence test performance in the present study reflect neurological rather than environmental factors, they suggest, in agreement with the findings for children with generalized brain damage and in contradiction with some of the findings for children and adults with lateralized brain



damage, that Verbal IQ is more frequently lowered as a result of lateralized brain dysfunction in children. More specifically, the results of the present study for the pattern of intelligence test performance suggest that the child with temporal lobe epilepsy maximally involving the left hemisphere is likely to have a lower Verbal than Performance IQ score, while the child with temporal lobe epilepsy maximally involving the right hemisphere is equally likely to have a lower Verbal IQ or lower Performance IQ.

## Reference Notes

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## Footnotes.

1. The data for this study were collected as part of a collaborative research project undertaken by the neurology and psychology departments of the IWK Hospital in Halifax. Only those details of the project which are relevant to the hypotheses under investigation were reviewed in this study.
2. The cutoff for age of onset was determined by plotting the distribution of this variable for the total sample and dividing this into two groups of equal n. Four subjects whose age of onset fell at the sample median of nine years were excluded from the t test and chi-square analyses.
3. Although the sample size for the present study was small (n of 26), it constituted a majority of the cases in the files which met the criteria of psychomotor seizures and a strictly lateralized temporal lobe spike discharge. Since the IWK Hospital services the Maritime region, the sample may at least be considered representative of children with lateralized temporal lobe epilepsy in the Maritime region.