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Reading abilities and cognitive functions of children with epilepsy: Influence of epileptic syndrome

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Summary

Children with epilepsy are at risk of developing learning disorders. To explore the influence of the epileptic syndrome on reading abilities, we have compared the neuropsychological profile of 12 children with benign idiopathic epilepsy with rolandic spikes, 10 with temporal lobe epilepsy and 12 with idiopathic generalized epilepsy. Children underwent a selection of standardised tests designed to assess: oral language, reading, short-term memory, attention and behavioural adjustment. Analysis of variance was adjusted according to age of onset of the epileptic syndrome, duration of the syndrome, and performance IQ for each group. Children with temporal lobe epilepsy (TLE) had significantly lower scores for reading speed and comprehension, but epileptic variables (the age of onset of epilepsy, duration and activity of epilepsy) had influenced academic performances. In the TLE group there was a clear effect of the topography of the epileptic foci (left-side TLE vs. right-side TLE) on reading profile. Furthermore, the effect of epileptic syndromes was found in phonological, semantic and verbal working memory deficits in the TLE group. To a lesser extent children with idiopathic generalized epilepsy (IGE) also exhibit cognitive deficit. The results of the present study lend support to epilepsy-specific patterns of neuropsychological dysfunction in children that should be considered to improve remediation of academic underachievement in these populations.

Keywords: Epilepsy; Rolandic epilepsy; Temporal lobe epilepsy; Reading abilities; Neuropsychology; Children

1. Introduction

Epilepsy cannot be confined to epileptic seizures. The psychological and cognitive consequences of epilepsy can have a major impact on the social and academic adjustment of patients with epilepsy. The learning difficulties (in mathematics, reading, spelling and writing) found in 1/3 of epileptic children [1] are frequently the consequence of specific cognitive disabilities [2] rather than a disorder of global intellectual function (the presence of mental retardation is estimated at 14%) [3] although the distribution of intelligence quotient (IQ) scores of children with epilepsy is skewed toward lower values [4]. Various factors are considered likely to induce cognitive disabilities: the age of onset, period of time since onset, the type of epilepsy, the nature and frequency of the seizures, and the effects of anti-epileptic treatment [5,6]. Moreover, interictal EEG discharges are implicated in transient neuropsychological disturbances and may contribute to the cognitive problems of some children with epilepsy [7,8]. Reading is a complex cognitive function, which in addition to acquired or learned cognitive abilities, depends on many intrinsic functions, including oral language, visuo-spatial capacities, attention, and short-term memory. For instance, in developmental dyslexia, the mainstream hypothesis implicates difficulties in phonological processing (reduced phonological awareness and short-term verbal memory) as the cause of reading disabilities [9]. Nevertheless some researchers

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underlines the role of other cognitive functions as visual attentional processing [10] that may contribute to reading performance. If epilepsy intervenes over the critical maturational stages of these functions, their development may be altered. Yet reading disorders in epileptic children have received little attention by authors since the study by Stores and Hart in 1976 [11].

The first aim of this study was to examine the reading abilities of three groups of children with a well-defined epileptic syndrome (temporal lobe epilepsy (TLE), benign childhood epilepsy with centrotemporal spikes (BCECTS), and idiopathic generalized epilepsy (EGI) by controlling a large number of variables that could provoke a specific effect in the development of learning disorders. Clinical heterogeneity in children with epilepsy populations is one of the main methodological biases in the studies of the impact of childhood epilepsies on cognitive development [2]. The second aim was to determine the impact of a specific cerebral dysfunction related to these reading difficulties and the role of the laterality of epileptic focus in TLE.

2. Patients and methods

The children included in this study were aged between 7 years 7 months and 12 years 9 months and were treated and studied for their epilepsy at the Henri–Gastaut's Hospital in Marseille and the Children's Hospital in Toulouse. Depending on the type of epileptic syndrome, three groups were established: an idiopathic generalized epilepsy group (IGE), a temporal lobe epilepsy group (TLE) and a benign childhood epilepsy with centrotemporal spikes group (BCECTS). Children of the first group presented absences or generalized tonic-clonic seizures, or an association of the two. Children in the second group had temporal partial epilepsy with either a normal magnetic resonance imaging (MRI) or focal cortical dysplasia or hippocampal sclerosis on MRI. Symptomatic temporal lobe epilepsies with diffuse lesions or tumours were excluded from this study. The third group involved children with benign childhood epilepsy with centrotemporal spikes. In this group all the children had sleep EEG recordings in order to eliminate children with continuous spikes-waves during slow sleep syndrome (CSWS). Mental retardation, as defined by an overall IQ of below 70 on the Wechsler Intelligence Scale for Children, was an exclusion criterion.

For each child, the following information was obtained: age of onset of the epilepsy, period of time between the first seizure and the last seizure (i.e. the duration of epilepsy), type of seizure, amount and name of the anti-epileptic drug(s) prescribed at the time of evaluation. The profession and academic level of children's parents were also recorded. Each child underwent a complete neuropsychological evaluation over two half-days. The references for each test used in this study are presented in Appendix 1.

A handedness-coefficient was established for all of the children with the Edinburgh Questionnaire recording which hand the child prefers for 10 daily activities.

The Conners Questionnaire was completed by both parents to detail the child's behaviour and to establish an index of hyperactivity.

Intellectual functions were evaluated by a French version of the Wechsler Intelligence Scale for Children-Third Edition (WISC III).

Reading level was assessed via two standardized French tests, 'l'Alouette' and 'Le printemps'. In the first test, the child had to read aloud a meaningless text as rapidly and accurately as possible, a performance from which a reading age (and a reading age discrepancy relative to chronological age) was calculated, taking speed and number of errors into account. In the second test reading level was calculated taking into account speed and text comprehension.

To assess the efficiency of lexical and sublexical procedures in reading aloud, performance were obtained on 20 irregular words and 20 pseudowords, 10 short and 10 long. Correct responses, latency times and duration of vocal response were recorded.

Skills associated with learning to read were also assessed: in term of rapid naming (color patches and numbers), short-term phonological memory and phonemic awareness. To assess phonological awareness, the child had to perform three deletion tasks of the first element of triplets: syllable deletion on 10 tri-syllabic items with a Consonant–Vowel structure; phoneme deletion on tri-phoneme pseudowords: 12 with a Consonant–Vowel–Consonant structure (CVC) and 12 with a Consonant–Consonant–Vowel structure (CCV).

Sustained attention was evaluated by a cancellation test (d2 Test); selective attention and ability to inhibit a non-relevant response were measured by the Stroop Test.

The Rey–Osterrieth Complex Figure Test enabled the analysis of visual-spatial organisational and planning ability.

For the receptive oral language abilities, a phoneme category perception test was carried out (discrimination test on a /ma/vs /na/phonetic continuum). The discrimination test was computerized and the child was asked to press one of two different keys according to whether he/she heard the syllable /ma/ or the syllable /na/. Auditory comprehension of semantic and lexical aspects of language was evaluated with the 'Ecosse' Test. The Ecosse Test entails a forced-choice among four pictures of the picture corresponding to the sentence that the examiner has just read aloud.

The expressive language functions and some written language capabilities were assessed using a standardized specific French battery, the Chevrie–Muller (L2MA) Language Evaluation Battery, including: phonological and semantic fluency tests, a visual confrontation naming task, assessing the passive lexical stock, and spelling tasks.

Memory span tests were also carried out: forward and backward digit spans (WISC III), non-word repetition span and visuo-spatial span (Corsi).

Statistical analysis was carried out using chi^2 or Fisher's exact tests to compare qualitative data and using variance analysis to test the difference between groups for each test exploring reading abilities. When quantitative data were not normally distributed, we used Kruskall–Wallis non-parametric tests. In order to take into account the effects of the duration of the epileptic syndrome, age of onset and level of intellectual functioning on performance test, a multivariate analysis was carried out. Statistical analysis was performed using Stata Statistical Software: Release 7.0. (Stata Corporation, College Station, TX).

3. Results

Thirty four patients were included in this study from May 2002 to November 2003. The mean age of the population was 115 months (SD = 19.4), and the sex ratio was 1.26, with 19 boys and 15 girls. There were no significant differences between the three groups for the following variables: age at time of inclusion, sex ratio, handedness (coefficient), socio-economic status, age of onset of epileptic syndrome, performance IQ and duration of epilepsy.

3.1. Epilepsy

The children in the BCECTS group had few seizures (10 of 12 children had had less than five attacks); the children in the IGE group suffered mainly from absences (although 6 of 12 children had experienced between 1 and 3 generalized tonic-clonic seizures, not withstanding one child who had experienced more than 10 generalized tonic-clonic seizures); the children in the TLE group frequently had seizures, varying from 2 to 3 attacks a day to 1 attack every 3 months. The IGE and TLE groups were different to the BCECTS group in treatment: in the BCECTS group half of the children were not under treatment, the other half received either valproate (4/6 children) or clobazam (2/6 children); in the IGE and TLE groups the children received a similar amount of medication although not the same agents: in the IGE group the children received either valproate, lamotrigine or ethosuximide; in the TLE group most children were administered either carbamazepine, topiramate or valproate (plus one child who was treated with phenytoin and another with vigabatrin). No family history of dyslexia was found in the three groups. Two children had a history of language delay in the IGE group (and had speech intervention) but none in the TLE or BCECTS groups. Six of ten subjects in the TLE group had functionally significant reading deficit and received speech therapy; this was also the case for three of 12 children in the BCECTS group and one of 12 children in the IGE group. The main clinical characteristics have been summarized in Table 1.

In the BCECTS group, six children presented a left centrotemporal focus and six a right centrotemporal focus on awake and sleep EEG recordings. Half of the 12 children had unfrequent spikes and waves, less than 5 per min, and the other half had frequent or very frequent spikes and waves (i.e. more than 10 per min) but none met criteria for continous spikes-waves during slow sleep syndrome (CSWS). In the IGE group, the EEG was normal in six children, two of the 12 children presented generalized spikes and waves only in response to intermittent photic stimulation and 4 of the 12 children had generalized spikes and waves spontaneously or during hyperventilation. Children were considered in remission if they were seizure free for at least 6 months with a normal EEG at the time of neuropsychological assessment. In the EGI group five children met these criteria. In the BCECTS group, all the children had persistent spikes on sleep EEG and in the TLE group, only one child was in remission (S3). Distribution of spikes and results of MRI for the TLE group have been summarized in Table 2.

3.2. Reading level and associated skills

Reading. Statistical analyses revealed significant a difference among the three groups in terms of reading speed level ($P = 0.03$) and reading understanding level ($P = 0.02$). Considering the reading age discrepancy (relative to the chronological age) for reading speed/accuracy ('l'Alouette' test), there was a significant difference

Table 1
Descriptive data of the sample

E Type (*n*)	IGE (12)	TLE (10)	BCECTS (12)	*P*
Sex (M/F)	7/5	5/5	7/5	0.90
Age (months)	109.9 (14.6)	126.7 (18.0)	112.4 (21.3)	0.09
Handedness Coefficient*	70 (40–100)	100 (−60–100)	90 (10–95)	0.72
Onset E (months)	73.4 (24.8)	76.1 (41.9)	86.7 (34.6)	0.61
Duration E (months)*	15.5 (5.5–49)	28 (5–92)	18.5 (5–36)	0.52
Performance IQ	92.4 (15.6)	96.5 (12.8)	102.2 (14.1)	0.26
AED (0/1/2/3)	0/8/3/1	0/3/4/1	6/6/0/0	<0.01
Family history of dyslexia	No	No	No	
Delay language acquisition	2/12	0/10	0/12	
Speech therapy for reading disabilities	3/12	6/10	3/12	

Mean (SDs) or *median (inter quartile range) depending on the data distribution. E, epilepsy; *n*, number; M, male; F, female; SD, standard deviations; IQ, intellectual quotient; AED, number of children with zero, one, two or three anti-epileptic drugs.

Table 2
Main EEG and MRI findings in TLE group

	Lateralization of the focus	Topography of temporal spikes	Frequency of interictal spikes	MRI results
S1	Right	Anterior	Frequent	Normal
S2	Right	Anterior	Frequent	Normal
S3	Left	Anterior	Frequent	Hippocampal sclerosis
S4	Left	Anterior	Rare	Normal
S5	Left	Posterior	Frequent	Focal cortical dysplasia
S6	Left	Posterior	Rare	Normal
S7	Right	Anterior	Frequent	Normal
S8	Right	Anterior	Rare	Normal
S9	Right	Anterior	Rare	Focal cortical dysplasia
S10	Left	Posterior	Rare	Focal cortical dysplasia

S, subject; MRI, magnetic resonance imaging.

between the TLE and BCECTS groups ($P=0.03$) but not between the TLE and IGE groups ($P=0.20$) or the BCECTS and IGE groups ($P=1.00$). On the test evaluating the speed and understanding of a text read by the child ('Le printemps'), the score was significantly lower in the TLE group than in the BCECTS group ($P=0.01$), whereas no differences were found between the TLE and IGE groups ($P=1.00$) and between the IGE and BCECTS groups ($P=0.09$). No significant differences were observed between the groups in lexical and sublexical procedures in reading, and in skills associated with learning to read: phonological awareness or rapid naming tasks (colors or numbers) (Table 3).

Oral language. Significant differences were found between the three groups in verbal ability, evaluated by the Wechsler scale (WISC III). Statistical analyses revealed a significant difference among the groups in verbal IQ ($P<0.01$). Scores of the children with TLE were significantly lower than those of the BCECTS group for the verbal IQ ($P<0.01$) and the vocabulary sub-test ($P<0.01$). Difference was not found in other comparisons, neither between the TLE and IGE groups: verbal IQ ($P=0.48$), vocabulary sub-test ($P=0.29$) nor between the IGE and BCECTS groups: verbal IQ ($P=0.13$), vocabulary sub-test ($P=0.08$). Language assessment revealed significant differences among the groups in expressive skills: vocabulary ($P=0.05$) and phonology (fluency task) ($P<0.01$). On vocabulary, there was a significant difference between the TLE group and the BCECTS group ($P=0.01$) but not between TLE and IGE groups ($P=0.46$) or the IGE and BCECTS groups ($P=0.25$). No significant differences were found among the groups in receptive language skills.

Verbal short-term memory—Differences were found between the groups on immediate verbal memory retention for the digit span ($P<0.01$). Statistical analysis revealed a significant difference between children with TLE and BCECTS ($P<0.01$) and between children with IGE and BCECTS ($P=0.03$). There was a tendency for children with TLE to score lower than the two others groups in short-term phonological memory ($P=0.07$).

3.3. Attention, visual-spatial abilities and behavioural adjustment

Attention. No significant differences were found between the groups in attention control, measured by the d2 Test (F%, $P=0.58$) and the Stroop Test (Interference Condition Score of errors, $P=0.70$).

Visual-spatial abilities. No significant differences were found in visual-spatial organisational and planning abilities measured by the Rey–Osterrieth Complex Figure test (score of copy, $P=0.87$) or by block design sub-test of WISC III ($P=0.75$). The immediate visual-spatial retention span, measured by the Corsi task, revealed no significant differences among the groups ($P=0.37$).

Behavioural adjustment. Conners Questionnaire showed significant differences between the groups in index hyperactivity. Analysis showed that the hyperactivity factor in the TLE group was higher than in the BCECTS group ($P=0.05$) but no significant difference was found between the TLE and IGE groups ($P=0.76$) or the IGE and BCECTS groups ($P=0.43$).

3.4. Analysis of the differences between groups after adjustment for performance IQ, duration of seizures and age at onset

Multivariate analysis only demonstrated significant differences between the groups in immediate verbal memory retention (digit span, $P=0.02$) and in phonological aspects (FLP, $P<0.01$) and semantic aspects (vocabulary L2MA, $P=0.04$; vocabulary WISC III, $P<0.01$; V IQ, $P=0.05$) of oral language.

3.5. Left-side and right-side temporal lobe epilepsies

The influence of the topography of the epileptic focus was studied by comparing the cognitive achievement of children with the right TLE ($n=5$) to those with the left TLE ($n=5$). Statistical analysis (Mann–Whitney test) showed significant differences between the two subgroups in several reading abilities and skills associated with

Table 3
Reading level and associated skills

E Type (*n*)	IGE (12)	TLE (10)	BCECTS (12)	*P*	*P***
Reading					
Alouette (months)	−10.3(21.5)	−25.9(24.3)	−3.2(11.1)	0.03	ns
Printemps (quartile)	2.2(1.3)	1.9(0.9)	3.2(1.0)	0.02	ns
Lexical procedure					
SIW CR %	58.3(34.1)	58(22.5)	65(26.8)	0.81	
LIW CR %	66.7(32.0)	70(26.7)	62.5(34.4)	0.86	
Sublexical procedure					
SPW CR %*	75(70–95)	80(60–100)	95(80–100)	0.20	
LPW CR %	67.5(20.9)	51(27.7)	71.7(24.1)	0.13	
Spelling (L2MA)					
Spelling PW (SD)	−0.7(0.9)	−1.1(1.1)	−0.6(1.0)	0.47	
Spelling Total Score (SD)	−0.3(1.2)	−0.7(1.3)	0.1(1.2)	0.50	
Verbal abilities (WISC III)					
V IQ	101.8(14.1)	92.9(15.7)	114.3(14.2)	<0.01	0.05
Vocabulary	11.1(2.6)	9.1(2.5)	13.7(3.0)	<0.01	<0.01
Oral Language (L2MA)					
Phonemic VF* (SD)	−1(−2–−1)	−1(−1–−1)	0.5(−1–1)	<0.01	<0.01
Semantic VF (SD)	−0.7(1.0)	−0.7(0.9)	0.1(0.9)	0.09	
Vocabulary (SD)	−0.5(0.7)	−1(0.8)	0.1(0.9)	0.01	0.04
Ecosse Test					
Errors score	9.3(3.1)	6.2(4.3)	6.3(4.0)	0.09	
Ma/Na Test					
Slope %	66.1(17.4)	51.3(23.1)	68.9(12.2)	0.09	
Phonological awareness					
SDT CR %*	75(60–90)	90(80–100)	90(85–100)	0.19	
SDT time	53.8(14.4)	45.0(17.1)	42.3(16.6)	0.20	
CVC CR %*	96(79–100)	92(92–100)	100(96–100)	0.23	
CVC time	44.1(12.0)	40.5(13.6)	41.7(15.4)	0.82	
CCV CR %	65.9(26.3)	68(22.8)	72.1(30.7)	0.85	
CCV time*	48.9(43.1–70.5)	57.1(46.3–70.3)	48.4(36.6–88.8)	0,69	
Rapid naming					
Colors (Stroop)	43.3(11.6)	53.6(8.2)	49.3(11.2)	0.09	
Numbers—Time	34.5(6.6)	29.3(6.0)	30.2(9.3)	0.23	
Short-term memory					
Digit span (*WISC III*)	9.4(3.0)	8.3(2.6)	12.4(2.5)	<0.01	0.02
Phonological span	3.9(0.8)	3.7(1.1)	4.6(0.9)	0.07	
Visuo-spatial span (*Corsi*)	4.1(0.8)	4.7(1.0)	4.6(0.9)	0.36	

Mean (Standard deviations) or *median (inter quartile range) depending on the data distribution. *P*** after adjustment: Age of onset of epileptic syndrome, Duration of epilepsy and P IQ. E, epilepsy; n, number; SD, standard deviations; CR, Correct Responses %; SIW, short irregular words; LIW, long irregular words; SPW, short pseudo-words; LPW, long pseudo-words; PVF, phonemic verbal fluency; SVF, semantic verbal fluency; SDT, syllable deletion task; CVC and CCV, phoneme deletion tasks in consonant-vowel-consonant and Consonant–Consonant–Vowel structures.

learning to read. The performance of children with left TLE was significantly lower than in children with right TLE on reading speed ('L'Alouette', $P=0.02$). The reading age in the left TLE (89 months ranging from 79 to 101) was significantly lower than that in the right TLE (115 months ranging from 99 to 127). Differences were also found in lexical and sublexical procedures in reading [Correct responses for reading short (SIW, $P=0.03$) and long irregular words (LIW, $P=0.05$) and short (SPW, $P<0.01$) and long pseudo-words (LPW, $P=0.02$)], in spelling [spelling score, $P=0.04$ or spelling pseudo-words, $P=0.02$], in rapid naming [RN numbers, $P=0.01$], in phonological awareness [Time for syllable deletion SDT Time, $P<0.01$, and accuracy for phoneme deletion CCV CR, $P=0.008$] (Fig. 1). Furthermore, qualitative analysis of the category perception test ('ma/na' discrimination) suggested a disparity between the right and left TLE groups inasmuch as the former seemed to show better discrimination than the latter Nevertheless statistical analysis showed no difference between children with left TLE and children with right TLE (Ma/Na, $P=0.09$) probably owing to the small number of children in this sample.

3.6. Impact of seizure frequency or epileptic discharges on cognitive function tests

We have studied the effect of seizure in the EGI group by comparing the cognitive achievement of children in remission (five children) to children not in remission (seven children). Statistical analysis (Mann–Whitney tests) showed no significant differences between the two subgroups for general cognitive functions and more specifically reading abilities. In the BCECTS group influence of spike index during sleep was analyzed by comparing cognitive

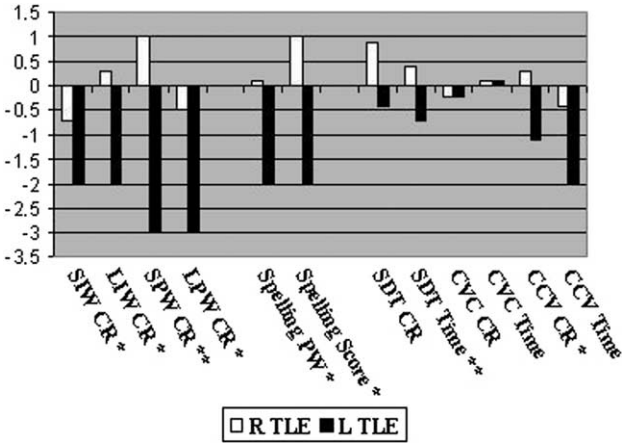

Fig. 1. Differences in reading and associated skills for patients with right and left TLE. *Y*-axis: all results are standard scores. *X*-axis: SIW, short irregular words; LIW, long irregular words; SPW, short pseudo-words; LPW, long pseudo-words; SDT, syllable deletion task; CVC and CCV, phoneme deletion tasks in consonant–vowel–consonant and Consonant–Consonant–Vowel structures; CR, correct responses; PW, pseudo-words*$P<0.05$-**$P<0.01$.

achievement of children with low spike index during sleep (<5/mn) and children with high spike index during sleep (>10/mn). Statistical analysis (Mann–Whitney tests) showed significant differences between the two sub-groups for semantic verbal fluency ($P=0.02$) and interference condition in Stroop test ($P=0.02$). In the TLE group the influence of epileptic discharges was studied by comparing children with rare spikes (five children) and children with frequent spikes (five children) as they were described in Table 2. Statistical analysis (Mann–Whitney tests) showed no significant difference between the two sub-groups.

4. Discussion

Our findings suggest a specific influence of the epileptic syndrome on phonological, semantic and verbal working memory abilities in the TLE group and a possible effect of the topography of the epileptic foci (left-side TLE vs. right-side TLE) on reading profile. Nevertheless epileptic variables have an impact on cognitive functions in each epileptic syndrome that is discussed in relation to their pathophysiology.

4.1. Influence of epileptic variables (seizure frequency, epileptic EEG discharges, antiepileptic drugs) for each group

Learning difficulties in epileptic syndromes have multiple causes. For neuropsychological studies one major obstacle lies in the control of the different variables related to the epileptic syndrome. In this study, the age at onset and the period of time since onset were evaluated for each group and their influence on the epileptic syndrome was analyzed. The frequency of seizures also plays a role in the genesis of cognitive disabilities in children with epilepsy and in this study the three groups varied in the rate of recurrence of seizures. Since some authors speculated seizure frequency has an impact on performance IQ [12], this variable was also taken into account during analysis. Epileptic interictal EEG discharges may influence neuropsychological findings in children with epilepsy. For instance in children with BCECTS various cognitive deficits have been reported despite rare seizures: some authors reported the role of the lateralization of the epileptic focus in the origin of cognitive dysfunction [13] whereas others find that neuropsychological deficits are better correlated with the frequency of spikes on the EEG recordings [14,15]. In this study, children with BCECTS and high spike index on sleep EEG were less efficient than children with low spike index for semantic verbal fluency and inhibitory control tasks. These tasks are dependent on frontal lobe function. In BCECTS there is no explicit involvement of frontal regions but this type of epilepsy can still affect large-scale neural networks subserving executive functions as already report by other authors [16]. Moreover Binnie et al. [7] have demonstrated that high discharge rates are associated with transitory cognitive impairments. However, in our study EEG was not recorded during neuropsychological testing and such a direct influence of discharges on cognitive functions could not be studied. Finally, antiepileptic drugs may also play a role in the cognitive disabilities of epileptic children, although some authors have questioned these effects. Comparing the neuropsychological profile of children with idiopathic epilepsy before and after antiepileptic therapy, Mandelbaum and Burack [17] reported no significant deterioration attributable to medication after 6 and 12 months of treatment with either valproate, carbamazepine or ethosuximide. However, in our study it was not possible to rule out possible effects of certain drugs, such as phenytoin or topiramate.

4.2. Influence of epileptic syndrome on reading abilities

In this study, reading difficulties were predominant in the TLE group as compared to the BCECTS group. However, the TLE group showed no significant differences to the IGE group. In most neuropsychological tests, the results in the BCECTS group did not deviate significantly from the mean of the population used to standardise the tests. As such, this group could be viewed as the control group. The small sample size of each group does not allow us to generalize this view to larger population since neuropsychological deficits have been reported even in this benign epileptic syndrome. Some authors as Bailet and Turk [18] showed that long-term risk of learning problem exists among children with idiopathic epilepsy. More specifically, Echenne et al. [19] have reported in childhood absence epilepsy, severe cognitive impairment which contradicted the benign character of this epileptic syndrome. Similarly in

this study, reading achievement in the IGE group was lower than that in the BCECTS group, although the difference did not reach significance. Several studies have reported impairment of sustained attention in patients with idiopathic generalized seizures and more precisely in the absence type. According to the cortico-reticular theory of absence epilepsy, this attentional effect may relate to impairment of the cortico-thalamic-reticular network [20]. After adjustment of the period of time since onset, the age at onset and performance IQ, the difference between the TLE and BCECTS groups was no longer significant in reading speed and reading comprehension. This result is in favour of the impact of these variables in relation to epileptic activity, independently of the epileptic syndrome, on certain aspects of reading ability.

4.3. Influence of epileptic syndrome on verbal and memory abilities

The three epilepsy groups in the present study did not differ significantly on tests assessing sustained attention and response inhibition, planning ability and visual-spatial and visual-construction skills. Specific influence of epileptic syndrome was found in several verbal language or memory abilities (Table 3). There was a significant impairment in the TLE and IGE groups for verbal memory (verbal short-term memory in Table 3), whereas no differences were found between the groups in the visual-spatial span ('Corsi' test in Table 3). For the digit span, the difference survived adjustment of the co-variables (performance IQ, duration since onset and age of onset of the epileptic syndrome). Short-term memory abilities heavily involve functions of the prefrontal cortex, but there is also some indication that the medial temporal region, which matures earlier than the prefrontal cortex, may mediate some aspects of short-term memory early in development [21]. During evaluation of oral language, differences were found between the groups in the phonological and semantic aspects of language. The active (word definition—sub-test vocabulary of WISC III in Table 3) and passive (denomination—sub-test vocabulary of L2MA in Table 3) lexical stocks were lower in the TLE group in comparison to the BCECTS group, whereas the difference was not significant between the IGE and BCECTS groups. The phonological fluency test (sub-test phonemic verbal fluency or PVF of L2MA in Table 3) showed weaknesses in the TLE and IGE groups. Poor performance on vocabulary and denomination scores has previously been reported in children with TLE [22]. Helmstaedter et al. [23], have found language disorders in 54% of 48 children candidates for epilepsy surgery with refractory TLE. In their study, Breier et al. [24] compared two groups of children with TLE, with and without reading disorders. Their results showed significantly lower verbal ability and verbal memory scores in the TLE group with reading difficulties. These studies including the present one confirm the role of temporal lobe regions in phonological and semantic linguistic processing [25], which suggests a specific effect of the type of epilepsy on language disorders.

4.4. Cognitive dysfunction in TLE and pathophysiology

Three children in the TLE group had a focal cortical dysplasia on MRI that was epileptogenic in all the cases. It may be that in spite of normal MRI results, other patients in this group also present microscopic lesions [26]. Organic lesions in TLE are likely to account for more marked cognitive dysfunction in this group relative to the EGI group in which epilepsy is both less severe and not likely to be associated with brain lesion.

The comparisons carried out between the two sub-groups of the TLE group, according to right or left localisation of the epileptic foci, suggested a specific effect since the left TLE group had lower scores on reading speed (Alouette test), lexical (correct responses reading in short and long irregular words—SIW and LIW) and sub-lexical (correct responses in reading short and long pseudo-words—SPW and LPW) reading tests, spelling (spelling pseudo-words and spelling total score of the L2MA) tests, and skills associated with learning to read, i.e. rapid naming (naming colors in the stoop test) and phonological awareness test (syllable or phoneme deletion tasks: SDT, CVC and CCV). The neuropsychological profile of the left TLE group was similar to the profile encountered in developmental dyslexia. Recent studies, using functional magnetic resonance imaging, gave evidence of dysfunction in left parietal-temporal and left occipital-temporal regions in developmental dyslexia [27]. Some studies highlighted these structures in temporal lobe epilepsy as well. Henry et al. [28] compared the group of patients with left TLE patients to a control group and demonstrated lack of activation in the left anterior fusiform gyrus in the TLE group during a naming task. Furthermore, in our study, analysis of the categorical perception slope (ma/na discrimination test) showed a tendency for less accurate categorisation in the left-TLE patients. According to Serniclaes et al. [29], phonological disorders in developmental dyslexia may stem from the category perception deficit, preventing the creation of stable phonological representations. Bougeard and Fischer [30] reported evoked potentials alterations in favour of a deficit in auditory processing function in patients with left TLE, bringing into question the role of these modifications in the genesis of the neuropsychological difficulties encountered in TLE.

Although similar works are needed in larger populations, this study suggests the existence of specific cognitive dysfunctions in relation to the type of epileptic syndrome; TLE patients seemed to be at-risk for developing reading disorders, and the neuropsychological profile of patients with left TLE is analogous to that observed in developmental dyslexia, a condition in which dysfunctions in the left perisylvian regions have been demonstrated. It would be interesting to compare the neuropsychological profiles of

patients with TLE according to the anterior or posterior localisation of the epileptic foci.

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Appendix A. References for neuropsychological tests used in the study

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