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Impaired facial expression recognition in children with temporal lobe epilepsy: Impact of early seizure onset on fear recognition

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Abstract

The amygdala has been implicated in the recognition of facial emotions, especially fearful expressions, in adults with early-onset right temporal lobe epilepsy (TLE). The present study investigates the recognition of facial emotions in children and adolescents, 8–16 years old, with epilepsy. Twenty-nine subjects had TLE (13 right, 16 left) and eight had fronto-central epilepsy (FCE). Each was matched on age and gender with a control subject. Subjects were asked to label the emotions expressed in pictures of children’s faces miming five basic emotions (happiness, sadness, fear, disgust and anger) or neutrality (no emotion). All groups of children with epilepsy performed less well than controls. Patterns of impairment differed according to the topography of the epilepsy: the left-TLE (LTLE) group was impaired in recognizing fear and neutrality, the right-TLE (RTLE) group was impaired in recognizing disgust and, the FCE group was impaired in recognizing happiness. We clearly demonstrated that early seizure onset is associated with poor recognition of facial expression of emotion in TLE group, particularly for fear. Although right-TLE and left-TLE subjects were both impaired in the recognition of facial emotion, their psychosocial adjustment, as measured by the CBCL questionnaire [Achenbach, T. M. (1991). Manual for the Child Behavior Checklist and Youth Self-report. Burlington, VT: University of Vermont Department of Psychiatry], showed that poor recognition of fearful expressions was related to behavioral disorders only in children with right-TLE. Our study demonstrates for the first time that early-onset TLE can compromise the development of recognizing facial expressions of emotion in children and adolescents and suggests a link between impaired fear recognition and behavioral disorders.

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Keywords: Children; Temporal lobe epilepsy; Facial emotion recognition; Behavior; Hemispheric specialization

1. Introduction

Children with refractory epilepsy often display academic difficulties and behavioral problems. Recent research in the neuropsychology of childhood epilepsy has provided evidence of specific cognitive profiles according to the localization of the epileptic process (Elger, Helmstaedter, & Kurthen, 2004; Jambaqué, Lassonde, & Dulac, 2001). Temporal lobe epilepsy (TLE) has been associated with language and memory impairments in adults (Helmstaedter, Lehnertz, Grunwald, Gleissner, & Elger, 1997; Jones-Gotman, 1986; Saykin, Gur, Sussman, O’Conner, & Gur, 1989), and more recently in children as well, both before and after surgery (Gleissner, Sassen, Schramm, Elger, & Helmstaedter, 2005; Jambaqué et al., 2007; Lendt, Helmstaedter, & Elger, 1999). Some children studies reported an effect of the side of epilepsy, with impairment of verbal functions in left temporal lobe epilepsy (LTLE) and of nonverbal functions in right temporal lobe epilepsy (RTLE) (Beardsworth & Zaidel, 1994; Fedio & Mirsky, 1969; Gadian et al., 1996; Jambaqué, Dellatolas, Dulac, Ponsot, & Signoret, 1993; Jambaqué et al., 2007; Szabo et al., 1998). Other studies failed to find this effect or found it to be less pronounced than in adults, which suggests that the effect of lateralization of the epileptic focus on specific cognitive functions

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is less relevant in children than in adults, particularly after temporal lobe surgery (Gonzalez, Anderson, Wood, Mitchell, & Harvey, 2007; Lendt et al., 1999; Mabbott & Smith, 2003).

On the other hand, children with TLE have high rates of psychopathology, such as mood and personality disorders, hyperactivity, conduct disorders and social difficulties or autism-like behaviors (Besag, 2004; Caplan et al., 2004; Carracedo et al., 1995; Deonna, Ziegler, Moura-Serra, & Innocenti, 1993; Kaminer, Apter, Aviv, Lerman, & Tyano, 1988; Neville et al., 1997; SBarra, Rimm-Kaufman, & Pianta, 2002). An important factor in determining the severity of the effect of epilepsy on cognitive and behavioral disorders is age of onset (Caplan et al., 2004; Cavazzuti & Nalin, 1990; Nolan et al., 2003; Saykin et al., 1989). Improvement of cognitive abilities, behavior, and quality of life has been reported after temporal lobe resection in children which argues in favor of early surgical intervention (Costa da Costa, 2002; Danielsson, Rydenhag, Uvebrant, Nordborg, & Olsson, 2002; Gleissner et al., 2005; Lendt, Helmstaedter, Kuczaty, Schramm, & Elger, 2000; Lendt et al., 1999; Lewis et al., 1996; Sinclair et al., 2003; Smith, Elliott, & Lach, 2004).

Since children with TLE display cognitive and psychosocial difficulties, neuropsychological investigations should assess both cognitive functions and socio-emotional abilities as well. Facial expressions are nonverbal cues that allow us to express and communicate our own emotions. They also allow us to recognize the emotions of others, which helps us to gauge the effects of our behavior on others and to adjust it accordingly. Recognizing emotions in the faces of others is an important social skill that facilitates appropriate interpersonal interactions (Harrigan, 1984) and, thus, justifies using facial photographs in research studies of emotion processing in children, adolescents, and adults (Ekman & Friesen, 1976; Herba & Phillips, 2004; McClure, 2000). Deficits of emotion processing are usually detected in brain-damaged and emotionally disturbed adults using Pictures of Facial Affect (Ekman & Friesen, 1976); a set of pictures of adult faces expressing six innate, universal emotions (happiness, sadness, anger, disgust, fear, and surprise), the so-called ‘basic’ emotions (Ekman, 1992; Ekman & Friesen, 1971).

Neural networks underlying facial emotion recognition involve a distributed set of structures that include the visual cortices, the amygdala, the orbitofrontal cortex, and additional cerebral regions, such as the insula, the basal ganglia, and the prefrontal cortex (Adolphs, 2002). The amygdala, which is often damaged with the hippocampus in patients with TLE (Miller, McLachlan, Boucher, Hudson, & Munoz, 1994; Pitkänen, Tuunanen, Kalviäinen, Partanen, & Salmenniemi, 1998), has been identified as an important structure for evaluating emotional stimuli, particularly potentially threatening and dangerous stimuli, and for regulating social and emotional behavior (Aggleton, 1992; LeDoux, 1992, 2000). In the mature monkey, bilateral damage of the amygdala produces an inability to evaluate the social and emotional meaning of visual stimuli and generates a lack of fear responses to inanimate objects and a “socially uninhibited” pattern of behavior (Amaral et al., 2003; Klüver & Bucy, 1939; Meunier, Bachevalier, Murray, Malkova, & Mishkin, 1999; Weiskrantz, 1956). In humans, there is evidence that bilateral lesions to the amygdala impair the recognition of emotions in facial expressions, fear particularly (Adolphs, Tranel, Damasio, & Damasio, 1994; Adolphs, Tranel, Damasio, & Damasio, 1995; Brooks et al., 1998; Calder et al., 1996; Sprenglemeyer et al., 1999). Severe impairment in recognizing fear can be included into a larger impairment in recognizing emotions of negative valence (Adolphs et al., 1999; Brooks et al., 1998; Calder et al., 1996; Sato et al., 2002; Schmolck & Squire, 2001; Sprenglemeyer et al., 1999). Similar or more subtle deficits in recognizing fear were reported in adults with TLE after right temporal lobe resection (Adolphs, Tranel, & Damasio, 2001; Adolphs, Baron-Cohen, & Tranel, 2002; Anderson, Spencer, Fulbright, & Phelps, 2000; Brierley, Medford, Shaw, & David, 2004; McClelland et al., 2006). However, these deficits are not related to the surgery exclusively, but also to the pre-existing epileptogenic lesion. A recent facial emotion recognition study of patients with RTLE indicated that their impairment in fear recognition existed before surgery (Melleti et al., 2003) and a functional magnetic resonance imaging study indicated that patients with RTLE, but not those with LTLE, failed to activate right temporal lobe structures during implicit processing of fearful expressions (Benuzzi et al., 2004).

Nevertheless, some adult patients with RTLE or bilateral amygdala damage perform normally in face-emotion recognition tasks (Adolphs et al., 1995; Adolphs et al., 2001; Anderson et al., 2000; Brierley et al., 2004; Hamann & Adolphs, 1999). The effect of a damaged amygdala on fear recognition may depend on the state of maturation of the amygdala when the damage occurs. Indeed, impaired fear recognition is observed in patients suffering from congenital disease or early-acquired bilateral amygdala damage (Calder et al., 1996; Hamann et al., 1996; Hamann & Adolphs, 1999) and in adults with RTLE whose seizures began early in childhood, especially before the age of 5–7 (Anderson et al., 2000; Adolphs et al., 2001; Benuzzi et al., 2004; McClelland et al., 2006; Melleti et al., 2003). These findings suggest that an early epileptic focus situated in the right mesial temporal lobe regions might delay or disturb or preclude the functional maturation of the neural networks mediating the processing and the interpretation of fear conveyed by facial expressions. This suggestion is consistent with the hypothesis that the right hemisphere is dominant for the perception of emotions both in adults (Adolphs, Damasio, Tranel, & Damasio, 1996; Borod et al., 1998; Bowers, Bauer, & Heiman, 1993) and children (Saxby & Bryden, 1985).

In normal development, neural networks for the processing of facial emotions mature progressively from early childhood until the end of adolescence (Batty & Taylor, 2006; Taylor, McCarthy, Saliba, & Degiovanni, 1999). Functional imaging studies indicate a functional maturation of the amygdala occurs during adolescence (Monk et al., 2003; Nelson et al., 2004) and that amygdala responses occur during the processing of fearful expressions in children and adolescents (Baird et al., 1999; Killgore, Oki, & Yurgelun-Todd, 2001; Lobauh, Bisson, & Taylor, 2006; McClure et al., 2004; Thomas, Drevets, Whalen...
et al., 2001). Developmental studies of children’s ability to detect and label emotions in pictures of facial expressions have described progressive improvement of performance between the ages of 5 and 15–16, except for happiness, which is accurately recognized from the youngest age (Gosselin, 1995; Lenti, Lenti-Boero, & Giacobbe, 1999; Tracy, Robins, & Lagattuta, 2005; Vicari, Reilly, Pasqualetti, Vizzotto, & Caltagirone, 2000). However, methodological differences between studies make it difficult to describe the trajectories of the development of the recognition of negative emotions (Herba & Phillips, 2004).

We recently developed a new task in which children label pictures of children miming five basic emotions (fear, anger, disgust, sadness, happiness) and a neutral expression, Test de Reconnaissance des Emotions Faciales pour Enfants (TREFE, Golouboff, Jambaqué, & Fiori, unpublished). With the TREFE, typically developing children are nearly perfect in recognizing happiness (99%), neutrality (98%) and fear (97%) and somewhat lower for anger (90%), disgust (85%) and sadness (80%).

In the present study, we used the TREFE to assess recognition of children’s facial emotions in 37 children and adolescents with focal drug-resistant epilepsy. The impact of TLE on recognition of children’s facial emotions was assessed by comparing the performances of 29 children and adolescents with TLE (13 right, 16 left), eight with extra-temporal frontocentral epilepsy (FCE), and 37 matched healthy children. Children with FCE constitute an epileptic control group, as epilepticogenic focus does not involve orbitofrontal cortex or prefrontal cortex, which are the cortical areas implicated in recognition of facial affect (Hornak, Rolls, & Wade, 1996). The performance of children with TLE was also compared to that of the large sample of typically developing children that was used to standardize the TREFE. We hypothesized that (1) the children suffering from an epileptic focus in the mesial temporal lobe regions would be impaired in emotion recognition, particularly fear; (2) emotion recognition impairments would be more pronounced in the children whose seizure activity began early in infancy than in the children whose seizures began later in childhood; and (3) the lateralization of the epilepsy would have an impact on emotion recognition performances, with the poorest recognition expected in children with RTLE. Finally, prior research has emphasized a relationship between psychopathology and face-emotion recognition. Many studies in children and adolescents note associations between reduced face-emotion recognition skills and anxiety/depression (Easter et al., 2005; Lenti, Giacobbe, & Pegna, 2000; McClure, Pope, Hoberman, Pine, & Leibenluft, 2003), social problems (Simonian, Beidel, Turner, Berk, & Long, 2001) and conduct disorders (Blair & Coles, 2000; Stevens, Charman, & Blair, 2001). Therefore, we also tested the hypothesis that TREFE scores of subjects with TLE will be related to their psychosocial adjustment. For psychopathology, behavioral profiles were assessed with the Achenbach Child Behavior Checklist (CBCL) (Achenbach, 1991), a widely used parental-report questionnaire to assess psychosocial disorders in children, especially in children with epilepsy (Dorenbaum, Cappelli, Keene, & McGrath, 1985; Hermann, Whitman, Hughes, Melyn, & Dell, 1988).
2. Methods

2.1. Participants

Thirty-seven children with epilepsy (21 girls), 8–16 years old, were evaluated between September 2004 and December 2006 at the Paediatric Epilepsy Neurosurgery Department of the Fondation Rothschild (Paris, France). The following selection criteria were used to select the children: (1) right-hand dominance, (2) mesial TLE or fronto-central epilepsy (FCE) involving motor, pre-motor or opercular regions, (3) enrollment in a normal school and (4) full-scale IQ score above 70 on the Weschler Intelligence Scale for Children – III (Weschler, 1991).

Twenty-nine of the children had TLE – 13 with right temporal lobe epilepsy (six treated surgically) and 16 with left temporal lobe epilepsy (nine treated surgically) and eight children had FCE (six were treated surgically). Anatomical MRI data were available for all the children. Children with surgery had undergone either a unilateral anteromemal temporal lobe resection (including the amygdala, the hippocampus and temporal pole) or a unilateral resection of the motor, pre-motor or opercular regions (but not of the orbito-frontal cortex). Demographical, neuropsychological and medical profiles of children with epilepsy are shown in Table 1. There was no significant difference in the profiles of the TLE and FCE groups. The number of boys and girls and the mean age of children in RTLE and LTLE groups were equivalent. However, the LTLE group had an earlier age of seizure onset and poorer verbal performances (IQ and naming) than subjects with RTLE. Finally, each subject with epilepsy was matched on age and gender to a healthy subject without epilepsy (n = 37).

2.2. Materials and procedures

A face recognition battery was used to investigate socio-emotional skills of the children with epilepsy. All of them were administered (1) a preliminary Face Matching Task to ensure that performance on the TREFE could not be related to perceptual deficits, (2) a Face Memory Task to assess their ability to recognize unfamiliar faces and finally, (3) the TREFE. Their parents filled the CBCL questionnaire. One girl with LTLE did not complete the Face Memory Task and the CBCL for one girl with LTLE was not returned.

2.2.1. Preliminary tests

2.2.1.1. Face Matching Task. We constructed a face identity matching task to assess visuo-perceptual ability to identify faces. Black and white photographs of children’s neutral faces were extracted from the face memory test of the NEPSY (Korkman, Kirk, & Kemp, 2003). Each trial was composed of a stimulus face on the top of a sheet of paper and four stimulus faces below it (the target stimulus and three distractors). Distractors were photographs of faces of different children matched to the target on sex, age and appearance. On each trial the subject had to point to one of the four faces on the bottom of the paper that they thought matched the target on the top of the paper. There were 16 trials. The score was the number of correct answers.

2.2.1.2. Face Memory Task. The Face Memory Task of the CMS (Cohen, 2000) was used to assess the subjects’ ability to remember faces. The subject was instructed to remember the color photographs of unfamiliar faces of children and adults. The photographs were presented one at a time for 2 s each. There were 12 faces to remember for children 5–8 years old and 16 faces for children 9–16 years old. Face memory was assessed immediately after presentation (immediate recognition) and 30 min later (delayed recognition). In each recognition phase, the stimuli were presented one at a time and the target stimuli were mixed with distractors (16 distractors for the youngest, 24 distractors for the oldest). The subject had to show the already seen faces. The number of correct answers and a standardized score were calculated (max = 20) by referring to normative data.

2.2.2. Facial recognition of emotions (TREFE)

The Test de Reconnaissance des Emotions Faciales pour Enfants (TREFE, Golouboff, Jambaqué, & Fiori, unpublished) is a computerized test for children and adolescents that evaluates their recognition of facial emotions expressed in the photographs of children and adolescents. The test includes 72 color pictures of 5–15 year-old children’s faces miming five basic emotions (fear, anger, disgust, sadness, happiness) and neutrality (no emotion). The test contains 12 items (six photographs of boys and six photographs of girls) of each facial expression (Fig. 1). Facial expressions of surprise, which share a number features similar to those expressed by fear (i.e., wide eyes, raised eyebrows, opened mouth) were not included to avoid confusion between these two emotions (Bullock & Russell, 1985; Ekman & Friesen, 1971; Rapcsak et al., 2000). As in Ekman’s test (Ekman & Friesen, 1976), we retained neutral faces to allow assessment of the ability to recognize positive and negative emotions relative to no emotion.

During their introduction to the TREFE, subjects had to read the printed names of the emotions and to give synonyms or examples of situations in which they might feel these emotions to prove that they knew their meaning. If necessary, the investigator explained the emotions in order to verify that the child understood the instructions.

Then, six practice stimuli (one for each facial expression) were used to familiarize the subjects with the task while receiving feedback from the experimenter: a picture of a child’s face expressing an emotion was presented on a computer screen until the subject labeled it or until 30 s passed without a subject response, at which time the subject was forced to supply a label. The subject had a list of the six possible labels (fear, anger, disgust, sadness, happiness, and neutrality) and was free to consult it. After the subject responded, the experimenter corrected its response if necessary and pressed a computer key, which recorded the first response and initiated the next picture: a cross on a black background appeared for 1000 ms, then, the next picture appeared on the screen.

The same procedures were used during administration of the TREFE, but no feedback was provided. Seventy-two pictures occurred in a sequence determined by an E-Prime software program, with the constraint of the same mean rank of presentation for each expression category. The total number of correct answers (out of 72) and correct answers for each facial expression (out of 12) were computed.

2.2.3. Behavioral profile

The CBCL (Achenbach, 1991) is an internationally used instrument for the assessment of behavioral disorders in children between 4 and 18 years of age. The questionnaire consists of 113 items to which parents respond with a number, 0 – not true at all, 1 – somewhat or sometimes true or 2

Fig. 1. Stimuli used in the TREFE. Girls’ and boys’ faces expressing fear, anger, disgust, sadness and happiness, as well as faces with neutral expression, were used.
– very true or often true. The CBCL contains Behavior Scales (withdrawn, somatic problems, anxious/depressed, thought problems, social problems, attention problems, aggression problems, and delinquency). The results for each scale are expressed as T-scores, with T-scores of 67–70 representing a ‘borderline clinical’ range, and T-scores above 70 indicating ‘pathological’ range. It also provides a general behavioral problem index (total score); an Internalizing Problems index that represents over-controlled behavioral problems (social withdrawal, somatic complaints, anxiety/depression) and an Externalizing Problems index that represents under-controlled behavior problems (aggression, delinquent behavior). Results for these three scales are also expressed as T-scores, with T-scores of 60–63 representing a ‘borderline clinical’ range, and T-scores above 63 indicating a ‘pathological’ range.

2.3. Data analysis

Statistical analyses were performed with Statistica 6.0 and SAS software version 6.0. Unresected and resected patients were grouped together because no significant effect of resection was found either for the face memory tasks or for the TREFE test.

3. Results

3.1. Preliminary tasks

3.1.1. Face matching

All children with epilepsy performed successfully in the face matching task which indicates that none of them had visuo-perceptual difficulties that would compromise face discrimination (Table 2).

3.1.2. Face memory

The RTLE group obtained the poorest performances in this task, and the RTLE and LTLE groups tended to recognize fewer faces than the FCE group, however these tendencies were not significant: $F(2, 33) = 1.69, P = .20$, for the immediate, and $F(2, 33) = 1.07, P = .36$ for the delayed recognition phases (Table 2). The correlation between face recognition memory and the age at onset of epilepsy was not statistically significant. Face recognition scores were negatively correlated with T-scores on the internalizing problems scale (immediate recognition, $r = -.48$, $P = .012$, and delayed recognition, $r = -.41$, $P = .036$), including the withdrawal scale (immediate recognition, $r = -.39$, $P = .05$ and delayed recognition, $r = -.40$, $P = .044$) and the anxiety/depression scale (immediate recognition, $r = -.46$, $P = .02$ and delayed recognition, $r = -.46$, $P = .02$). These correlations indicate that the memory for faces of introverted, anxious or depressed children with TLE was lower than that of children with TLE without internalizing problems.

3.2. Facial recognition of emotions (TREFE)

3.2.1. Impact of presence and localization of the epileptogenic zone

3.2.1.1. Mean accuracy

Age was significant on the mean overall accuracy at the TREFE, $F(1, 69) = 4.95$, $P = .003$, however mean age was similar in all groups. The effect of the group on overall performance was significant, $F(1, 69) = 4.92$, $P = .004$. All groups of children with epilepsy (RTLE, LTLE, and FCE

Table 2 Mean recognition scores of the controls and of the children with frontal lobe epilepsy (FCE), right temporal lobe epilepsy (RTLE) and left temporal lobe epilepsy (LTLE) on the face matching, face memory and TREFE tests

<table>
<thead>
<tr>
<th></th>
<th>Controls ($n = 37$)</th>
<th>FCE ($n = 8$)</th>
<th>RTLE ($n = 13$)</th>
<th>LTLE ($n = 16$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate recognition/20</td>
<td>–</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Delayed recognition/20</td>
<td>–</td>
<td>11.8 (3.0)</td>
<td>9.5 (2.9)</td>
<td>10.3 (3.6)</td>
</tr>
<tr>
<td>TREFE</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total score/72</td>
<td>66.1 (3.0)</td>
<td>62.8 (6.4)</td>
<td>62.6 (7.6)</td>
<td>60.7 (6.4)$^a$</td>
</tr>
<tr>
<td>Fear/12</td>
<td>11.6 (6.8)</td>
<td>11.8 (5.5)</td>
<td>11.4 (1.0)</td>
<td>10.1 (3.0)$^a$</td>
</tr>
<tr>
<td>Anger/12</td>
<td>10.7 (1.5)</td>
<td>10.5 (2.3)</td>
<td>10.8 (1.2)</td>
<td>10.5 (1.5)</td>
</tr>
<tr>
<td>Disgust/12</td>
<td>10.7 (1.4)</td>
<td>9.0 (3.4)</td>
<td>8.6 (3.9)$^a$</td>
<td>9.4 (2.6)</td>
</tr>
<tr>
<td>Sadness/12</td>
<td>9.3 (1.6)</td>
<td>8.6 (1.8)</td>
<td>9.0 (2.4)</td>
<td>8.4 (2.6)</td>
</tr>
<tr>
<td>Happiness/12</td>
<td>11.9 (3.3)</td>
<td>11.4 (7)$^a$</td>
<td>11.8 (4.4)</td>
<td>11.6 (7)</td>
</tr>
<tr>
<td>Neutral/12</td>
<td>11.8 (6)</td>
<td>11.5 (1.1)</td>
<td>11.1 (1.4)</td>
<td>10.7 (1.1)$^a$</td>
</tr>
</tbody>
</table>

$^a$ Group-values performance significantly lower than controls ($P < .05$).
groups) performed lower relative to controls (Table 2), however, post-hoc analyses of the means revealed that the LTLE group only obtained a mean overall performance significantly lower than controls. Analyses by emotion showed significant group differences for fear, $F(1, 69) = 4.08$, $P < .01$, disgust, $F(1, 69) = 3.11$, $P = .03$, neutrality, $F(1, 69) = 5.32$, $P = .002$, and marginally for happiness, $F(1, 69) = 2.64$, $P = .056$. Post-hoc comparison of the means revealed that (1) the LTLE group was significantly impaired for the recognition of fear relative to all the other groups, and for neutrality relative to controls and FCE groups; (2) the RTLE was significantly impaired relative to controls for the recognition of disgust, and (3) the FCE group was significantly impaired relative to controls and RTLE groups for the recognition of happiness. No significant difference was found for anger and sadness ($P$-values $>.05$).

### 3.2.1.2. Emotion effect and emotion by group interaction on accuracy

There was a main effect of emotional category, $F(5, 66) = 23.8$, $P < .001$. The interaction group by emotion was significant, $F(15, 182.6) = 2.00$, $P < .02$. Performance of controls was better for happiness, neutrality and fear than for recognition of anger, disgust and sadness (in a decreasing order) (all $P$-values $>.05$, except between happiness, neutrality and fear).

This indicates that, in typically developing children, fear is the third best recognized emotion, easier to recognize than the three other negative emotions (anger, disgust and sadness). It has been noted that surprise, which is often confused with fear, was not included in our task. The children with epilepsy showed a somewhat different emotional ordering pattern relative to controls, with different places of fear or disgust according to the topography of the epilepsy. Fear was less well recognized than anger by the children with LTLE (fear in fourth position) whereas fear was better recognized than happiness by the children with FCE (fear in first position). Disgust was less well recognized than sadness by the children with RTLE and by the children with FCE (disgust in last position).

Like typically developing children, LTLE patients often misinterpreted fearful expressions as disgust (61% of the errors for fear recognition), and RTLE patients misinterpreted disgusted expressions as anger (73% of the errors for disgust recognition). In contrast, for neutral faces, LTLE children made atypical errors by misinterpreting them as anger (43% of the errors for neutral faces recognition) whereas typically developing children rather misinterpreted them as sadness (39% of the errors for neutral faces recognition). FCE children made atypical errors for the recognition of happy faces by misinterpreting them as fear (57% of the errors for neutral faces recognition) whereas typically developing children rather misinterpreted them as neutral faces (53% of the errors for neutral faces recognition). This suggests a bias toward negativity in the recognition of emotions in children with FCE.

### 3.2.2. Influence of the age at epilepsy onset and of febrile convulsions

For children with TLE, age-adjusted total score (Z-score) on the TREFE were positively correlated with the age at onset of the first temporal lobe seizure ($r = .51$, $P = .006$) which indicates that earlier onset of temporal lobe seizures led to worse performances for the recognition of facial expressions. We observed positive correlations between Z-scores for each facial expression and the age at onset of the first temporal lobe seizure, but these correlations did not reach a significant threshold (all $P$-values $>.05$). With regard to the impact of febrile convulsions on emotion recognition, we found that children with TLE who had experienced febrile convulsions during infancy obtained a mean recognition Z-score for fear ($M = 3.0$, $S.D. = 3.7$) significantly lower than children with TLE without history of febrile convulsions ($M = 1.0$, $S.D. = 9.9$), $t(27) = 3.36$, $P = .002$. In contrast, the impact of febrile convulsions was not statistically significant for the other emotional expressions. There was no significant association between presence or absence of febrile convulsions and age at onset of the first temporal lobe seizure, $t(27) = .36$, $P = .73$.

### 3.2.3. Correlations with CBCL scores

RTLE group obtained higher CBCL scores, particularly for internalizing problems, than FCE and LTLE groups, but this tendency was not significant ($P$-values $>.05$ for all scales of the CBCL) (Table 3). RTLE patients showed the highest CBCL scores for internalizing (anxiety/depression, withdrawal) and social problems, followed by attention deficit, conduct problems and thought disorders. LTLE patients often showed social and internalizing problems and, in a less extend, attention deficit and conduct disorders. There was no significant correlation between CBCL scores and age at onset of temporal lobe epilepsy. FCE patients showed the highest CBCL scores for internalizing (anxiety/depression, withdrawal), social problems and attention deficit, followed by thought disorders. None of the children with FCE showed conduct disorders.

Correlations between age-adjusted TREFE scores (Z-scores) and CBCL scores were statistically significant in the group of children with RTLE, but only for the emotion of fear. In contrast, the correlations in children with LTLE were not statistically significant, for any expression. For fear recognition, Z-scores of the children with RTLE were negatively correlated with T-scores on almost all the CBCL scales, which indicates that, in the RTLE group, the poorest performances for fear recognition were obtained by the children who had the highest rates of

<table>
<thead>
<tr>
<th>Behavioral scales</th>
<th>FCE patients ($n = 8$)</th>
<th>RTLE patients ($n = 13$)</th>
<th>LTLE patients ($n = 15$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Withdrawn</td>
<td>25%</td>
<td>39%</td>
<td>7%</td>
</tr>
<tr>
<td>Somatic complaints</td>
<td>18%</td>
<td>23%</td>
<td>–</td>
</tr>
<tr>
<td>Anxious/depressed</td>
<td>38%</td>
<td>39%</td>
<td>20%</td>
</tr>
<tr>
<td>Social problems</td>
<td>25%</td>
<td>39%</td>
<td>33%</td>
</tr>
<tr>
<td>Thought problems</td>
<td>18%</td>
<td>15%</td>
<td>7%</td>
</tr>
<tr>
<td>Attention problems</td>
<td>25%</td>
<td>31%</td>
<td>20%</td>
</tr>
<tr>
<td>Delinquence</td>
<td>–</td>
<td>15%</td>
<td>13%</td>
</tr>
<tr>
<td>Aggression problems</td>
<td>–</td>
<td>15%</td>
<td>13%</td>
</tr>
<tr>
<td>Internalizing problems</td>
<td>50%</td>
<td>62%</td>
<td>27%</td>
</tr>
<tr>
<td>Externalizing problems</td>
<td>–</td>
<td>31%</td>
<td>20%</td>
</tr>
<tr>
<td>Total problems</td>
<td>38%</td>
<td>62%</td>
<td>47%</td>
</tr>
</tbody>
</table>
Withdrawn −.58∗
Somatic complaints −.24
Anxious/depressed −.59∗
Social problems −.62∗
Thought problems −.82**
Attention problems −.74**
Delinquency −.61*
Aggression problems −.71**
Internalizing problems −.55*
Externalizing problems −.66*
Total problems −.64*

Hemisphere × Fear indicates if the correlations are significantly different between RTLE and LTLE patients.
∗ P < .05.
** P < .01.
*** P < .001.

psychopathological disorders. In contrast, correlations between emotion recognition Z-scores and behavioral disorders in the group of children with LTLE were positive and not significant, which indicates that, contrary to the children with RTLE, impairments in emotion recognition were not related to behavioral disorders. The interaction between fear recognition performance and the side of the TLE was significant for all the scales of the CBCL (except somatic complaints), which confirms that the relationship between fear recognition and psychopathological disorders was not the same for the group of children with RTLE and the group of children with LTLE (Table 4). No significant correlation was found between happiness recognition Z-scores and behavioral disorders in the group of children with FCE.

3.2.4. Analysis of individual differences
3.2.4.1. Proportion of children with deficient recognition of facial emotions. The large individual differences in TREFE performances of the children with epilepsy suggest that some of them were impaired in emotion recognition whereas others were not. In order to establish the extent of impairments in TLE and FCE samples and then, in RTLE and LTLE samples, we assessed how many individuals in each sample obtained a recognition score that was significantly lower than the scores of typically developing children: we considered subjects whose recognition Z-scores fell below −2 S.D. to be impaired. We made this assessment for the total score and for each of the six expressions. Given because of the not normal distribution of the scores, we verified that all children with −2 S.D. obtained a score lower than the 5th percentile of the normative data. Table 5 indicates the total proportion of impaired subjects for each emotion for each group of children with epilepsy. Three of the 13 RTLE subjects, four of the 16 LTLE subjects and two of eight FCE subjects were considered to be impaired for overall performance at the TREFE. Considering scores per expression category, we observed that some individuals (three RTLE, four LTLE and two FCE) showed impaired recognition of several expressions but other children with epilepsy (six RTLE, four LTLE, two FCE) showed impaired recognition of only one expression. Impairment of fear was observed in six TLE children (four left, two right). In contrast, none of the children with FCE was impaired for fear recognition. Impaired fear recognition tended to be more frequent in LTLE group (4 of 16) than in the RTLE group (2 of 13), and impaired recognition of disgust more frequent in the RTLE group (4 of 13) than in the LTLE group (2 of 16), however these differences were not statistically significant, given the small number of subjects in each group.

3.2.4.2. Children with deficient recognition of fear. Here we focus on the medical history and the neuropsychological profiles of the six individuals with fear recognition deficit (see Table 6). These six children had TLE (four left, two right). Five of them showed additional deficiency for the recognition of one or two other emotions, and one child showed fear-specific impairment. All of them experienced febrile convulsions during infancy whereas only 26% of the children with TLE who performed successfully did. The difference was significant (t Fisher exact, P = .002) (Fig. 2). In addition, five of them (four left, one right) began temporal lobe seizures before the age of 5. Their

<table>
<thead>
<tr>
<th>Behavioral scales</th>
<th>RTLE patients (n = 13)</th>
<th>LTLE patients (n = 15)</th>
<th>Hemisphere × Fear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z-scores</td>
<td>Z-scores</td>
<td>F(1, 24)</td>
</tr>
<tr>
<td>Withdrawn</td>
<td>−.58*</td>
<td>−.02</td>
<td>6.91</td>
</tr>
<tr>
<td>Somatic complaints</td>
<td>−.24</td>
<td>.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Anxious/depressed</td>
<td>−.59*</td>
<td>−.02</td>
<td>5.21</td>
</tr>
<tr>
<td>Social problems</td>
<td>−.62*</td>
<td>.27</td>
<td>6.34</td>
</tr>
<tr>
<td>Thought problems</td>
<td>−.82***</td>
<td>.04</td>
<td>10.57</td>
</tr>
<tr>
<td>Attention problems</td>
<td>−.74**</td>
<td>.17</td>
<td>7.77</td>
</tr>
<tr>
<td>Delinquency</td>
<td>−.61*</td>
<td>.39</td>
<td>8.91</td>
</tr>
<tr>
<td>Aggression problems</td>
<td>−.71**</td>
<td>.27</td>
<td>11.02</td>
</tr>
<tr>
<td>Internalizing problems</td>
<td>−.55*</td>
<td>.07</td>
<td>4.48</td>
</tr>
<tr>
<td>Externalizing problems</td>
<td>−.66*</td>
<td>.48</td>
<td>13.88</td>
</tr>
<tr>
<td>Total problems</td>
<td>−.64*</td>
<td>.24</td>
<td>9.29</td>
</tr>
</tbody>
</table>

Table 4
Correlations between fear recognition Z-scores and behavioral disorders in the group of children with FCE.

Table 5
Proportion of children with epilepsy who were impaired at the TREFE per emotion type (recognition Z-scores below −2 S.D. of typically developing children’s ratings)

<table>
<thead>
<tr>
<th>Number of patients</th>
<th>FCE (n = 8)</th>
<th>RTLE (n = 13)</th>
<th>LTLE (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impaired total score</td>
<td>25%</td>
<td>23%</td>
<td>31%</td>
</tr>
<tr>
<td>Impaired at least for one expression</td>
<td>63%</td>
<td>62%</td>
<td>44%</td>
</tr>
<tr>
<td>Fear</td>
<td>–</td>
<td>15%</td>
<td>25%</td>
</tr>
<tr>
<td>Disgust</td>
<td>25%</td>
<td>31%</td>
<td>12%</td>
</tr>
<tr>
<td>Sadness</td>
<td>–</td>
<td>8%</td>
<td>12%</td>
</tr>
<tr>
<td>Anger</td>
<td>25%</td>
<td>8%</td>
<td>12%</td>
</tr>
<tr>
<td>Happiness</td>
<td>38%</td>
<td>15%</td>
<td>19%</td>
</tr>
<tr>
<td>Neutral</td>
<td>12%</td>
<td>23%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Note: FCE, fronto-central lobe epilepsy; RTLE, right temporal lobe epilepsy; LTLE, left temporal lobe epilepsy.
Table 6

<table>
<thead>
<tr>
<th>Subject</th>
<th>Surgery</th>
<th>Age (years)</th>
<th>FC</th>
<th>Age at first TLE</th>
<th>Lesion</th>
<th>Behavioral problems</th>
<th>VIQ/PIQ</th>
<th>Naming (Z-score)</th>
<th>Digit span (forward)</th>
<th>Face memory immediate/delayed/20</th>
<th>Fear (Z-score)</th>
<th>Additional deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 (boy)</td>
<td>No</td>
<td>14.5</td>
<td>Yes</td>
<td>22 months</td>
<td>HS</td>
<td>Internalizing, externalizing, attention deficit</td>
<td>103/88</td>
<td>−0.8</td>
<td>5</td>
<td>87</td>
<td>−3.7</td>
<td>Depressed, internalizing, externalizing, social, thought, attention</td>
</tr>
<tr>
<td>R2 (girl)</td>
<td>No</td>
<td>16.7</td>
<td>Yes</td>
<td>13 years</td>
<td>HS</td>
<td>Internalizing, attention deficit of the amygdala</td>
<td>92/91</td>
<td>1.8</td>
<td>7</td>
<td>57</td>
<td>−4.5</td>
<td>Depression, happiness, internalizing, externalizing, social, thought, attention</td>
</tr>
<tr>
<td>L1 (boy)</td>
<td>Yes</td>
<td>16.7</td>
<td>Yes</td>
<td>4 years</td>
<td>CD</td>
<td>Internalizing, attention deficit of the amygdala</td>
<td>86/99</td>
<td>−2.4</td>
<td>4</td>
<td>66</td>
<td>−6.6</td>
<td>Sadness, internalizing, externalizing, social, thought, attention</td>
</tr>
<tr>
<td>L2 (girl)</td>
<td>Yes</td>
<td>8.10</td>
<td>Yes</td>
<td>2 years</td>
<td>HS</td>
<td>Internalizing, attention deficit of the amygdala</td>
<td>80/99</td>
<td>−3.7</td>
<td>5</td>
<td>100</td>
<td>−9.0</td>
<td>Depression, happiness, internalizing, externalizing, social, thought, attention</td>
</tr>
<tr>
<td>L3 (girl)</td>
<td>Yes</td>
<td>10.2</td>
<td>Yes</td>
<td>11 months</td>
<td>HS</td>
<td>Internalizing, attention deficit of the amygdala</td>
<td>88/107</td>
<td>−5.6</td>
<td>5</td>
<td>100</td>
<td>−8.0</td>
<td>Anger, happiness, internalizing, externalizing, social, thought, attention</td>
</tr>
<tr>
<td>L4 (girl)</td>
<td>No</td>
<td>15.9</td>
<td>Yes</td>
<td>5 months</td>
<td>HA</td>
<td>Depression, attention deficit of the amygdala</td>
<td>106/76</td>
<td>−0.3</td>
<td>5</td>
<td>11/7</td>
<td>−9.3</td>
<td>Anger, happiness, internalizing, externalizing, social, thought, attention</td>
</tr>
</tbody>
</table>

Note: FC, febrile convulsions; DNET, dysembryoplasic neuroepithelial tumor; HS, hippocampal sclerosis; CD, cortical dysplasia; HA, hippocampal atrophy.

MRI or pathologic diagnosis indicated hippocampal sclerosis or atrophy. Among these children, three had undergone temporal lobe resection including the left amygdala. For the two other children (presurgical patients), the MRI did not reveal amygdala damage but only the pathological diagnosis of the resected tissue can give definite information regarding the nature and the extent of lesion. The other individual was a 16-year-old girl (R2) who began temporal lobe seizure later in childhood. Her MRI revealed right amygdala damage (Fig. 3).

The two adolescents with RTLE (R1 and R2) who were impaired in recognizing fear were not surgically treated. They had a relatively low PIQ and exhibited the highest rates of psychopathology (‘borderline’ or ‘pathological’ T-scores on all the scales of the CBCL, except somatic complaints). They had a poor visual contact and, in spite of preserved verbal skills, they rarely spoke spontaneously and had trouble expressing their feelings. They had poor self-esteem and were anxious and nervous (internalizing problems). They were lonely; they did not approach others and had few or no friends (social problems). They were dreamy and could not concentrate (attention problems). They displayed mannerisms, obsessions and compulsive behaviors or repetitive acts (thought problems). They also exhibited verbal and physical aggressive behaviors such as insults, unprovoked screaming fits, episodic attacks of rage and violence against others (externalizing problems). R2, who had an amygdala lesion, was also severely depressed: she made multiple auto-mutilations and suicide attempts. Her case is strongly suggestive of the link between amygdala damage, impaired fear recognition and depression.

Among the four children with LTLE that were impaired in recognizing fear (L1–L4), three had resections (L1, L2, and L3). All four had a relatively low VIQ. These children had trouble expressing their thoughts (naming problems) and feelings in everyday life. They had also a poor visual contact and poor self-esteem. They were anxious and nervous. However, in contrast to the two children with RTLE, none of them exhibited conduct disorders or aggressive behavior; which strongly suggests that the link between fear recognition impairments and psychopathology (e.g. externalizing problems) is not the same in the RTLE group and in the LTLE group (Fig. 4). The case L4 appeared to be unique among the children with LTLE. In contrast to the other cases (L1, L2, L3), she had an intellectual efficiency characterized by a visuo-verbal dissociation in favor of verbal functions, which strongly suggests that she had an atypical hemispheric specialization, and a behavioral profile that looked like that of the case R1 (depression, thought problems).

4. Discussion

The aim of this study was to assess the ability of children and adolescents with partial epilepsy to recognize facial expressions of emotion using an original paradigm adapted for youths, the TREFE. In spite of their average intellectual level and full success on a face recognition task, some children with RTLE, LTLE and FCE were impaired in recognizing facial expressions of emotion relative to controls and showed differential patterns of deficits according to the localization of the epileptogenic zone.
Fig. 2. Fear recognition Z-scores of the children with TLE who experienced febrile convulsions and of the children with TLE who did not.

Fig. 3. Sagittal (1a) and coronal (1b) MRI shows the damage of the right amygdala in case R2.

Fig. 4. Relationship between T-scores for externalizing problems and Z-scores for fear recognition in the children with right temporal lobe epilepsy (RTLE) and left temporal lobe epilepsy (LTLE).
Relative to controls, LTLE group was impaired in recognizing fear and neutrality, RTLE group was impaired in recognizing disgust and children with FCE were impaired in recognizing happiness. Individual analyses showed fear recognition impairments in some children with TLE, not in the FCE group. This is in agreement with findings from previous studies that provide evidence for fear recognition impairments in adults with TLE, “surprise” being included (Adolphs et al., 2001, 2002; Anderson et al., 2000) or not (Melleti et al., 2003) as one of the basic emotions in the paradigm. This confirms our hypothesis and clearly implicates temporal lobe structures in the development of fear recognition. However, we did not find a specific association between RTLE and errors on the TREFE task. Rather, we observed more frequent fear recognition deficits in children with LTLE than in children with RTLE. An earlier age at onset of epilepsy in the LTLE group than in the RTLE group, could contribute to this observation. In addition, although previous studies in children with TLE reported material-specific memory deficits (Jambaque et al., 1993; Nolan et al., 2004) and impaired face memory in children with RTLE (Beardsworth & Zaidel, 1994; Mabbot & Smith, 2003), the RTLE and the LTLE group did not differ significantly on the face memory task. However, there is evidence of atypical language lateralization in early-onset LTLE adults (Liégeois et al., 2004; Pataraa et al., 2004; Weber et al., 2006) and children (Yuan et al., 2006). Thus, although our children with TLE were all right-handed, one cannot exclude the possibility that several individuals have atypical language lateralization, e.g. case L4. Nevertheless, on the cognitive level, the recognition and the labeling of emotion in faces requires both the capture of the perceptual properties of the facial expression its link to knowledge of the concept and name of the emotion category. According to this view, the right hemisphere would be especially involved for encoding perceptual information about the facial emotion (preverbal ability) and the left hemisphere would be especially involved for the lexical retrieval of the knowledge and the name of the emotion (verbal ability) (Adolphs, 2002). Our analysis of the neuropsychological profiles of the children with TLE who were impaired in fear recognition (except L4 who appears to be a special case) revealed that the children with LTLE but not in children with RTLE had naming problems (Jambaque & Dellatolas, 2000), which has been reported in previous studies (Davies et al., 1994; Hermann, Wyler, & Sones, 1991; Jambaque et al., 2007). Thus, although subjects were free to consult the list of names of the emotions, it can be hypothesized that LTLE group-values poor overall performance in our facial expression recognition task was due to an inability to retrieve semantic verbal knowledge about emotion, thus, preventing the link between the percept of the facial expression (that may be intact) and the name of the emotion. In contrast, impairments in some of the children with RTLE may not be due to verbal or categorizing disability but rather to a more profound deficit at the perceptual stage of emotion processing. It would be interesting to compare emotion recognition performances of the children with RTLE and LTLE using different tasks, e.g., implicit recognition via a pointing task vs. explicit recognition via a labeling task, to verify this hypothesis.

4.1. Impact of early seizure activity on the development of fear recognition

We observed a great inter-individual variability in fear recognition performances of the children with TLE; some showed impairments whereas others performed similarly to controls. The fact that not all the children with TLE were impaired in recognizing facial expressions is consistent with previous evidence that unilateral mesiotemporal lobe damage does not invariably impair recognition of fearful expressions (Adolphs et al., 1995). Our study provided evidence that an early age of epilepsy onset may be crucial in causing facial emotion recognition deficits in children with TLE. In particular, the present data suggest that febrile convulsions, which generally occur early in life (i.e., 6–18 months of age, much earlier than the mean age at onset of TLE) can affect the ability of the children with TLE to recognize fear. This observation is in agreement with findings from adult studies in which it was the age of the first seizure (febrile or afebrile) that was found to be critical for emotion recognition (Adolphs et al., 2001; Benuzzi et al., 2004; Melleti et al., 2003). This supports the existence of a crucial period, possibly before the age of 5 years, for establishing the neural network that underlies emotion recognition. Chronic TLE is often associated with hippocampal and amygdala damage in adults and children (Miller et al., 1994; Pitkänen et al., 1998) and more pronounced volume reductions to the mesial temporal lobe structures were found in patients who had experienced prolonged febrile seizures early in life (Cendes et al., 1993; Wu et al., 2005). Our finding that all the TLE children who had experienced febrile convulsions were impaired in recognizing fear supports the hypothesis that developmentally early seizure onsets and damage of the mesiotemporal lobe structures (rather than the duration of the epilepsy) can generate impairments in fear recognition in the children with TLE.

Our data showed for the first time that early-onset TLE can compromise the ability to recognize facial emotions in childhood. Furthermore, impaired recognition of facial expression occurred both before and after surgery, which suggests that fear recognition deficits in adults with early-onset TLE (surgical cases or not) is a developmental disorder and that their deficit may have been detected earlier if they had been assessed during childhood.

4.2. Temporal lobe epilepsy, facial expression recognition and behavioral disorders

The present study confirms the high prevalence of behavioral problems in children and adolescents with TLE. Behavioral problems were found in multiple domains – internalizing problems (anxiety/depression, social withdrawal), externalizing problems, thought disorders and attention deficits, consistent with reports of previous studies (Besag, 2004; Caplan et al., 2004; Kaminer et al., 1988; Lendt et al., 2000; SBarra et al., 2002). Children with RTLE tend to have the highest rates of psychopathology and we demonstrate that deficits in recognizing fear are related to psychosocial adjustment difficulties in the RTLE group only, not in the LTLE group. This suggests
We did not expect children with FCE to be impaired in emotion recognition. Indeed, we selected them because the epileptogenic zone was not localized in an area that has been implicated in emotion recognition (the orbitofrontal cortex). However, there is evidence of connections between the lateral and caudal areas of the orbitofrontal cortex and the premotor areas or frontal opercular areas (Kringlebach & Rolls, 2004). It can also be hypothesized that the diffusion ‘at distance’ of the epileptogenic discharges may have a deleterious impact on the maturation and the functioning of the prefrontal cortex, which may generate impairments in emotion recognition in some of the children with FCE. Interestingly, impairments in recognizing facial expressions of the FCE group concerned happiness.

4.4. Limitations of the study and perspectives

The present results, and especially the differential impact of fear recognition impairment on psychopathology in right and left TLE, need to be confirmed with larger samples of patients with TLE. Diminished processing speed is acknowledged to be a primary cognitive morbidity in chronic TLE subjects (Dow, Seidenberg, & Hermann, 2004) and it would be interesting to analyze response times of children with epilepsy during facial emotion assessment. In addition, our study has focused on the recognition of emotion in static stimuli but it would particularly interesting to explore emotion recognition in children with epilepsy using dynamic stimuli since there is evidence that such stimuli can improve the recognition and discrimination of emotions compared to static displays (Werhle, Kaiser, Schmidt, & Scherer, 2000). Finally, it would also be interesting to assess facial emotion recognition in children with TLE both before and after surgery to explore the impact of temporal lobe resection on the development of this socio-emotional skill.

5. Conclusion

Our study is the first to demonstrate emotional dysfunction in children with TLE. Early-onset TLE can lead to selective impairments in the explicit recognition of fear in children which suggests that the integrity of the mesial temporal lobe structures during infancy is essential for the development of the processing and the appropriate interpretation of threatening signals conveyed by faces. If our findings of impairments for fear recognition in children with TLE only, but not in children with FCE, are confirmed on a larger sample of patients, then the evaluation of facial affect recognition abilities in youth with drug-resistant epilepsy can yield information on the localization of the seizure focus and the testing of facial affect recognition competencies might become a useful part of the neuropsychological evaluation of children with epilepsy. In all cases, emotional disorders should be considered when evaluating the quality of life and social adjustment in children with epilepsy. In this context, rehabilitation projects would include programs that train children to understand emotion and that teach them the specific emotion depicted by a facial expression. It is tempting to hypothesize that such programs would be useful to improve social communication skills of children with epilepsy.
Acknowledgments

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References


