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Facial emotion perception and social competence in children (8 to 16 years old) with genetic generalized epilepsy and temporal lobe epilepsy☆

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ABSTRACT

Facial emotion perception (FEP) impairments are common in adults with epilepsy and associated with impaired psychosocial functioning. Research into the presence of FEP deficits in children with epilepsy and the functional implications of these deficits is limited. The primary aims of this study were to assess FEP abilities in children (8 to 16 years old) with genetic generalized epilepsy (GGE) and temporal lobe epilepsy (TLE) and examine whether FEP is related to everyday social functioning. Forty-four children (8 to 16 years) with epilepsy (22 GGE, 22 TLE) and 22 typically developing controls completed the Pictures of Facial Affect (POFA) battery to assess FEP and a brief test of intellectual functioning (intelligence quotient [IQ]). Parents completed questionnaires assessing social competence of their child. Neurologists completed the Global Assessment of Severity of Epilepsy (GASE) scale as a measure of overall epilepsy severity. Demographic and clinical information was obtained from medical records and clinical interviews with parents. Findings revealed significant, overall FEP impairments and reduced social competence in children with GGE and TLE compared to controls. The magnitude of FEP impairment (i.e., across all emotions) was comparable in the two epilepsy groups, yet different emotions were impaired in each group: children with GGE were impaired in recognizing anger and disgust, whereas children with TLE were impaired in sadness and disgust, compared to controls. Contrary to expectations, total FEP accuracy was not significantly correlated with social competence in either epilepsy group. In conclusion, children with GGE and TLE have significant impairments recognizing emotional expressions on faces. Further research is needed to examine whether underlying FEP impairments relate to social and emotional functioning in children with epilepsy.

1. Introduction

Facial emotion perception (FEP) is the ability to accurately identify and label emotional expressions on faces [1]. It is a fundamental social cognitive skill that is important for healthy social and emotional development in children with and without neurodevelopmental and psychological disorders [2–4]. A growing body of research has shown that adults with temporal lobe epilepsy (TLE) and genetic generalized epilepsy (GGE) have significant impairments in FEP, which are related to psychosocial problems [5–8]. However, research into FEP abilities of children and adolescents (8 to 16 years old; hereafter referred to as 'children') with epilepsy is limited, with only three studies published so far [9–11]. Moreover, the functional correlates of FEP abilities in children with epilepsy have not been comprehensively studied. This is important, as studies suggest that social difficulties are prevalent in children with TLE [12] and GGE [13], yet sociocognitive factors underpinning these difficulties are not well understood.

Abbreviations: CBCL, child behavior checklist; FEP, facial emotion perception; GASE, global assessment of severity of epilepsy scale; GGE, genetic generalized epilepsy; POFA, pictures of facial affect task; SDQ, strength and difficulties questionnaires; SIEFA, Australian Bureau of Statistics Socio-Economic Index for Areas; SRS, social responsiveness scale; TLE, temporal lobe epilepsy; ToM, Theory of Mind.

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Facial emotion perception has been associated with the functional integrity of a distributed neural network in the temporal and frontal lobes, including the medial prefrontal cortex (mPFC), inferior parts of the frontal cortex (frontal operculum) and, anterior and posterior superior temporal sulcus (STS), and the amygdala [14–17]. In children with epilepsy, seizures and/or pathology that interfere with functioning of these neural regions may interfere with the development of FEP. Moreover, the age of seizure onset may affect the pattern of FEP impairments, as the developmental trajectories of FEP have been found to differ between basic facial emotions [18]. Recognition of happy faces approaches adult accuracy by 5 years old, whereas other emotions take longer to develop. Fear, anger, and disgust are typically recognized by 6, 9, and 11 to 12 years old, respectively [19–21]. Recognition of sadness is said to develop more gradually, with basic recognition present at 5 years old, but full accuracy not achieved until 10 to 11 years old [19–21]. Finally, children acquire full FEP ability at around 12 years old. Furthermore, because FEP not only relies on healthy brain development, but is also related to demographic and social/environmental factors (e.g., socioeconomic status [SES], family functioning, peer relationships), its emergence may also be affected by these variables in children with epilepsy [22,23].

Despite risk of FEP impairment, a recent meta-analysis found that only three published studies have examined FEP in children with epilepsy so far [24]. All of these studies included children with focal epilepsies (i.e., temporal, frontal, and extratemporal/frontal lobe epilepsy), and although all found evidence of FEP deficits, the specific emotions that were impaired differed between studies [9–11]. In addition, although understanding the functional implications of FEP impairments is of clinical importance, only one study has examined relationships between FEP and social and emotional functioning in children with epilepsy (i.e., children with TLE) [9]. This study found that poorer fear recognition was correlated with more social problems in children with right TLE (RTLE), but not left TLE (LTLE). The conclusions that can be drawn from this single study are limited, as the sample sizes of each group were small ($N = 13$ and 16 for RTLE and LTLE, respectively), and the authors relied on a single measure of social functioning (i.e., Social Problems subscale from the Child Behavior Checklist [CBCL], 6–18 years [25]), rather than using a broader assessment of social competence that includes positive and negative aspects of social behavior. Further research is needed to examine whether FEP is related to social competence in children with epilepsy, as well as whether FEP impairments are present in children with GGE. The dearth of studies examining FEP in children with GGE represents a significant gap in the literature, as GGE is common in childhood and associated with marked social difficulties [13].

Finally, understanding how epilepsy factors, such as seizure variables (i.e., age of seizure onset, duration of epilepsy, seizure frequency, epilepsy severity, side of seizure focus) and treatment factors (i.e., medication, surgery) relate to FEP impairments is important for clinical management of children. Earlier onset of seizures [9] and longer duration of epilepsy [10] have been related to reduced FEP in children with focal epilepsies. The relationship between overall epilepsy severity and FEP has not been examined. With respect to seizure laterality, no differences have been found between children with LTLE and RTLE in total FEP accuracy [9,11]. Similarly, treatment factors such as antiepileptic drugs (AEDs) and epilepsy surgery have not been related to impaired FEP in children with focal epilepsies [10]. A longitudinal study of children with TLE found no change in FEP performance pre- to postsurgery: FEP impairments that were present prior to surgery persisted at two-year follow-up [10]. Further research is needed to determine whether seizure variables and treatment factors relate to FEP impairment in children with GGE. Accurate identification of clinical variables may help to identify children at risk of FEP impairment and social difficulties.

1.1. Study aims and hypotheses

The primary aims of this study were to determine whether FEP deficits are (i) present in children with GGE and TLE, (ii) emotion specific, and (iii) related to everyday social impairments. The secondary aim was to examine whether facial emotion recognition is related to seizure variables and treatment factors, including those that are (i) common among children with GGE and TLE (i.e., age of onset, duration of epilepsy, seizure frequency, overall epilepsy severity, number of AEDs) and (ii) specific to children with TLE (i.e., side of seizure focus, surgical status). We hypothesized that children with GGE and TLE would perform more poorly on a test of FEP compared to controls and that FEP impairments would correlate with social competence problems. Given that this is the first study to examine FEP in children with GGE and limited research exists on FEP in children with TLE, we did not have specific hypotheses about differences in FEP accuracy between the two epilepsy groups. We planned to perform exploratory analyses to examine correlations between FEP and epilepsy variables (i.e., age of seizure onset, duration of epilepsy, seizure frequency, epilepsy severity, and number of AEDs; side of seizure focus and surgical status).

2. Materials and methods

Ethics approvals were obtained from participating hospitals.

2.1. Participants

The sample consisted of 44 children with epilepsy (22 with GGE and 22 with TLE) and 22 typically developing controls.

2.1.1. Children with epilepsy

Children with epilepsy were recruited from neurology/neurosurgery departments at three tertiary pediatric epilepsy services in Australia between February 2016 and April 2018: the Children's Hospital at Westmead, Sydney Children's Hospital Randwick and the Royal Children's Hospital in Melbourne. Inclusion criteria for children with epilepsy were as follows: (1) diagnosis of GGE or TLE made by treating neurologists, as per International League Against Epilepsy (ILAE) classification guidelines [33], (2) aged 8 to 16 years old at time of assessment, (3) fluent in English, (4) full scale intellectual quotient (FSIQ) > 70, (5) absence of major developmental/psychiatric conditions (i.e., autism), sensory/motor impairments (i.e., cerebral palsy, significant visual/hearing impairments), major neurological disorder (e.g., severe brain injury) or comorbid systemic and metabolic disorders that could lead to cognitive impairment, (6) absence of a neurological procedure/surgery in the previous 6 months, and (7) considered to have active epilepsy or epilepsy that is not yet considered 'resolved' according to the ILAE criteria as having an age dependent epilepsy syndrome but being past the applicable age or remaining seizure-free for the past 10 years and off antiseizure medicines for at least the last 5 years [26]. Thus, all children included who were seizure-free had been seizure-free for less than 10 years and off AEDs for less than 5 years. A postoperative period of 6 months was selected as findings have shown that seizures posttemporal lobe resection generally stabilize within 6 months of surgical resection, with seizure relapse present in less than 2% of cases after 6 months [27].

A total of 48 children with GGE and 36 children with TLE were identified as eligible by treating neurologists (DG, RW, JL) and invited to participate. In the group with GGE, 12 participants declined participation because of parental work ($N = 4$), school ($N = 2$), or cocurricular ($N = 6$) commitments, and 12 were unable to be contacted. In the group with TLE, 10 declined to participate because of parental work commitments ($N = 2$), cocurricular constraints ($N = 1$), or participation in another research project ($N = 7$), and 3 were unable to be contacted. Twenty-four children with GGE and 23 children with TLE were assessed. Two children with

GGE and one child with TLE were excluded because of having FSIQs < 70. There were no significant differences in demographic characteristics of children who participated and those who did not (see supplemental tables).

All children had received a diagnosis of epilepsy from their treating neurologist, according to ILAE classification guidelines [28]. Children with GGE were diagnosed with the following epilepsy syndromes: childhood absence epilepsy (CAE, $N = 6$), juvenile absence epilepsy (JAE, $N = 5$), juvenile myoclonic epilepsy (JME, $N = 6$), epilepsy with myoclonic absences (EMA, $N = 3$), or unclassified generalized epilepsies ($N = 2$). In the group with TLE, all children had unilateral TLE with seizure focus in the left (LTLE, $N = 14$) or right (RTLE, $N = 8$) hemisphere. Ten of the 22 children with TLE had undergone unilateral temporal lobe surgery (6 left, 4 right) for refractory epilepsy. Mean age at surgery was 11.50 years ($SD = 2.80$), and mean time since surgery was 33.91 months ($SD = 34.65$). The remaining 12 children with TLE were either waitlisted for surgery ($N = 5$) or were not considered candidates for epilepsy surgery ($N = 7$).

2.1.2. Control children

Control children with no history of epilepsy or seizures and neurological or psychiatric conditions were recruited over the same period of time through colleagues of investigators and acquaintances of colleagues (i.e., passive snowballing). Children were invited to contact researchers if they were interested in participating. The same inclusion criteria were applied, except for a diagnosis of epilepsy. All control children assessed met criteria and were included in the study.

2.2. Measures

2.2.1. Demographic variables

Demographic information (age, gender) was obtained in interviews with parents. An estimate of SES was obtained using the Australian Bureau of Statistics Socio-Economic Index for Areas (SIEFA), which assigns a quartile rank ranging (1 to 10) based on residential address, with a higher rank assigned to higher SES [29]. Socioeconomic status was included as it has been related to FEP development, and we wanted to control for potential differences between groups [23].

2.2.2. Intelligence

An estimate of intelligence (FSIQ; $M = 100$, $SD = 15$) was obtained by administering the four subtests from the Wechsler Abbreviated Scale of Intelligence–Second Edition (WASI-II; Block Design, Matrix Reasoning, Vocabulary, Similarities) [30]. FSIQ was assessed as it has been found to relate to social competence in children with epilepsy and we wanted to control for potential differences between groups [31].

2.2.3. Epilepsy variables

Overall epilepsy severity was measured by the Global Assessment of Severity of Epilepsy (GASE) scale, a validated single-item scale that rates epilepsy severity from 1 (not at all severe) to 7 (extremely severe), which was completed by a treating neurologist [32]. Other epilepsy variables collected included age of seizure onset, duration of epilepsy, seizure frequency over the past 12 months (i.e., average number of seizures the child had experienced each week, over the past 12 months), and number of AEDs. Additional information about seizure laterality and surgical status was obtained for children with TLE: side of seizure focus, age at surgery, time since surgery, and details of surgical resection (if applicable).

2.2.4. Facial emotion perception

The Pictures of Facial Affect (POFA) battery was used to assess children's recognition of five basic facial emotions (happiness, sadness, fear, disgust, anger) and a neutral expression [33]. A sixth facial emotion assessed on the POFA, surprise, which shares many similar features with fear (i.e., wide eyes, raised eyebrows) was not included to avoid confusion between emotions [34]. For each face shown, children were asked to choose one of 5 emotion labels that best described the facial emotion. Each face was presented on a separate slide in horizontal orientation on an iPad (9.7-inch screen). The image was displayed on the left hand side of the screen, taking up half of the screen, and emotion labels were presented on the right side of the screen (Size 20, Arial font, white text on black background). Children completed a trial set consisting of 6 photos (1 of each facial emotion), which was followed by a test phase consisting of 30 photos (5 of each facial emotion). A total percentage correct score was generated for each facial emotion, and for total FEP accuracy. A higher score on the POFA indicates better FEP accuracy.

2.2.5. Social competence

Parents completed three standardized questionnaires assessing social competence of their child. Subscales were selected based on Rantanen and Eriksson's [35] theoretical model of social competence in childhood epilepsy, which outline three core domains of social competence (social adjustment, social performance, social communication) that are grounded in Cavell's [36] tripartite model. Social adjustment was assessed with the social competence scale of the CBCL 6–18 years (t-scores were used to compare groups, $M = 50$, $SD = 10$) [25]. Social performance was evaluated with the prosocial behavior subscale of the Strength and Difficulties Questionnaires (SDQ, total adjusted raw scores were used to compare groups, range = 0 to 20) [37]. Social communication was measured with the social communication subscale of the Social Responsiveness Scale (SRS, total raw-scores were used to compare groups, range: 40 to 114) [38]. A higher score on each scale indicated better social competence.

2.3. Procedure

The medical records of children with epilepsy were reviewed and screening interviews were conducted with parents of all children over the phone to obtain relevant medical and developmental history, and establish eligibility for the study. All children were assessed individually in a single two-hour testing session, with short rest breaks. Assessments were conducted by a psychologist (ES) in clinical consultation rooms at participating hospitals, the University of Sydney or participants' homes. Children completed behavioral tasks assessing FEP and IQ, and parents completed questionnaires assessing social competence and emotional and behavioral functioning of their child. Treating neurologists completed the GASE as a measure of overall epilepsy severity.

2.4. Statistical methods

Data analysis was performed using the Statistical Package for Social Sciences (SPSS, version 25.0). Normality of distributions was examined with histograms and Shapiro–Wilk tests. One-way analysis of variance (ANOVA) and chi-square tests were conducted to compare groups on continuous and categorical demographic variables, respectively. Significant ANOVAs were followed by independent samples *t*-tests. On the POFA, data violated assumptions of normality. Thus, nonparametric tests were used: Kruskal–Wallis test assessed overall differences between groups and Mann–Whitney *U* tests examined difference between each epilepsy group and controls. Multivariate analysis of covariance (MANCOVA) was used to examine between-group differences across measures of social competence: CBCL social competence, SDQ peer problems, SRS social communication. Assumptions for MANCOVA were tested and met prior to analysis, and FSIQ was included as a covariate as it differed significantly between groups. For significant MANCOVA, the procedure outlined by Bray and Maxwell [39] was used for multivariate posthoc tests: three separate univariate analysis of covariance (ANCOVAs) compared groups on each social competence measure. When ANCOVAs were significant, posthoc independent sample *t*-tests were carried out to examine pairwise comparisons between groups. Guidelines provided by Bray and Maxwell [39] were used for decisions regarding family and experiment-wise error rates: we

controlled for family wise error with an adjusted alpha of 0.007 for analyses of FEP and 0.005 for analyses of social competence. For all other analyses, the level of statistical significance was set at 0.05 and *p*-values were adjusted with Bonferroni correction to control for multiple comparisons. Spearman's rank-order correlations examined correlations between POFA scores, social competence, epilepsy and demographic variables, and IQ. Correlations were first examined for each epilepsy group separately, and then epilepsy groups were collapsed to determine whether correlations were significant for the combined group, as per guidelines by Cohen [40]. Only total FEP accuracy on the POFA was examined in correlational analyses to minimize the number of statistical tests performed. Effect size estimates were calculated and classified using guidelines from Cohen [41]: eta squared (η^2) was used for ANOVA (0.01 = small, 0.06 = medium, 0.14 = large), Cohen's *d* was used for independent samples *t*-tests (0.3 = small, 0.5 = medium, 0.8 = large) and *r* was used for Mann–Whitney *U* tests (0.1 = small, 0.3 = medium, 0.5 = large) [41,42].

3. Results

3.1. Demographic variables and IQ

Table 1 displays descriptive statistics of demographic variables and IQ for children with epilepsy and controls and tests of between-group differences. There were no significant differences between groups for age, gender, or SES. Groups differed significantly for FSIQ, and posthoc tests showed that controls had significantly higher FSIQ than children with GGE ($t_{42} = 5.588$, $p < 0.001$, $d = 1.685$) and TLE ($t_{42} = 2.756$, $p = 0.009$, $d = 0.831$), and children with TLE had significantly higher FSIQ than children with GGE ($t_{42} = -3.138$, $p = 0.003$, $d = 0.947$). Despite these significant between-group differences in IQ, subsequent analyses did not control for IQ as controlling for IQ has been deemed inappropriate when the differences between groups are seen as an inherent characteristic of a disorder (please see Adams, Brown, & Grant [43]; Dennis et al. [44]; Tupper & Rosenblood [45]), such as in epilepsy. Moreover, FEP data were not normally distributed, meaning that it was not appropriate to include IQ as a covariate in these analyses.

3.2. Epilepsy variables

Descriptive statistics of epilepsy variables and tests of between group differences (GGE vs. TLE) are presented in Table 2. There was no significant difference between children with GGE and TLE for any epilepsy variable (Table 2).

3.3. Pictures of facial affect (POFA) task

Fig. 1 displays percentage correct responses on the POFA for children with GGE, TLE, and controls. Bonferroni corrections were used to control family wise error rate, and an adjusted alpha of 0.007 was used for analyses. Kruskal–Wallis tests revealed significant between-group differences in percentage correct responses for total FEP accuracy ($H = 17.456$, $df = 2$, $p < 0.001$), recognition of sadness ($H = 10.101$, $df = 2$, $p = 0.006$), and disgust ($H = 16.098$, $df = 2$, $p < 0.001$), but not happiness ($H = 2.203$, $df = 2$, $p = 0.332$), anger ($H = 8.729$, $df = 2$, $p = 0.013$), fear ($H = 7.851$, $df = 2$, $p = 0.050$), or neutral faces ($H = 4.464$, $df = 2$, $p = 0.107$). Pairwise comparisons with Mann–Whitney *U* showed that children with GGE performed significantly below controls in total FEP accuracy ($U = 67.00$, $z = -4.142$, $p < 0.001$, $r = 0.62$), recognition of disgust ($U = 76.50$, $z = -3.971$, $p < 0.001$, $r = 0.59$), and anger ($U = 123.00$, $z = -2.922$, $p = 0.003$, $r = 0.44$), but not happiness ($U = 220.00$, $z = -0.869$, $p = 0.385$, $r = 0.13$), sadness ($U = 139.50$, $z = -2.514$, $p = 0.012$, $r = 0.38$), fear ($U = 165.00$, $z = -2.249$, $p = 0.025$, $r = 0.34$), or neutral ($U = 198.00$, $z = -2.071$, $p = 0.038$, $r = 0.31$) faces. Children with TLE performed significantly below controls in total FEP accuracy ($U = 125.00$, $z = -2.767$, $p = 0.006$, $r = 0.42$) and in recognition of sadness ($U = 120.00$, $z = -3.006$, $p = 0.003$, $r = 0.45$) and disgust ($U = 129.00$, $z = -2.727$, $p = 0.006$, $r = 0.41$), but not happiness ($U = 231.00$, $z = -0.591$, $p = 0.554$, $r = 0.09$), anger ($U = 158.00$, $z = -2.070$, $p = 0.038$, $r = 0.31$), fear ($U = 241.50$, $z = -0.020$, $p = 0.984$, $r = 0.01$), or neutral ($U = 198.00$, $z = -2.071$, $p = 0.038$, $r = 0.31$) faces. Children with GGE and TLE did not differ significantly from each other in total FEP accuracy or any specific emotions ($ps > 0.05$).

3.4. Social competence

MANCOVA revealed a statistically significant difference between groups across measures of social competence (Pillai's value = 0.326, $F(3,118) = 3.835$, $p = 0.002$). One-way ANCOVAs showed that groups differed significantly in CBCL social competence ($F(2,64) = 9.387$, $p < 0.001$, $\eta^2 = 0.238$) and SRS social communication ($F(2,64) = 6.290$, $p = 0.003$, $\eta^2 = 0.173$), but not SDQ prosocial behavior ($F(2,64) = 0.466$, $p = 0.630$, $\eta^2 = 0.015$). Further pairwise comparisons showed that children with GGE performed significantly below controls on CBCL social competence ($t_{42} = 4.442$, $p < 0.001$, $d = 1.339$) and SRS social communication ($t_{42} = -3.425$, $p = 0.001$, $d = 1.033$), but not SRS prosocial behavior ($t_{42} = -0.179$, $p = 0.859$, $d = 0.054$). Children with TLE performed significantly below controls on SRS social communication ($t_{42} = -3.188$, $p = 0.003$, $d = 0.961$), but not CBCL social competence ($t_{42} = 2.240$, $p = 0.031$, $d = 0.675$) or SRS prosocial behavior ($t_{42} = 0.386$, $p = 0.702$, $d = 0.116$). Children with GGE and TLE did not differ significantly from each other in any social competence scores ($ps > 0.05$).

3.5. Correlations between POFA and social competence scores in children with epilepsy

Correlations between total FEP accuracy on the POFA and social competence scores were not significant for children with GGE or TLE. The two epilepsy groups were then collapsed to determine whether correlations were significant for the combined group, as per guidelines by Cohen [40]: correlations were not significant for the pooled epilepsy group (see supplemental tables).

Table 1
Background variables for children with GGE and TLE and controls: descriptive statistics (means and standard deviations or frequencies) and tests of significance.

	Controls ($n = 22$)	GGE ($n = 22$)	TLE ($n = 22$)	Test of significance[a]	*p*-Value	Effect size[b]
Age	12.43 (2.26)	12.82 (2.80)	13.87 (2.21)	$F_{2,63} = 9.405$	0.244	$\eta^2 = 0.044$
Gender (M/F)	10/12	8/14	11/11	$\chi^2 = 0.861$	0.650	$r = 0.114$
SES	7.27 (2.91)	6.50 (2.72)	6.91 (3.46)	$F_{2,63} = 6.576$	0.703	$\eta^2 = 0.011$
FSIQ	111.41 (13.76)	90.96 (10.27)	101.05 (11.04)	$F_{2,63} = 16.567^{**}$	<0.001	$\eta^2 = 0.345$

GGE, genetic generalized epilepsy; TLE, temporal lobe epilepsy; FSIQ, full-scale intellectual quotient. All tests were two-tailed. Significance $^{**}p < 0.01$.

[a] Results are from ANOVA and chi-square tests.

[b] Effect sizes estimates for F-tests are eta-square (0.01 = small, 0.06 = medium, 0.14 = large) and for chi-square tests, effect size estimate is *r* (0.10 = small, 0.30 = medium, 0.50 = large).

Table 2
Epilepsy variables for children with GGE and TLE: descriptive statistics (means and standard deviations or frequencies) and tests of significance.

	GGE ($n = 22$)	TLE ($n = 22$)	Test of significance	p-Value	Cohen's d[a]
Age of seizure onset (years)	6.36 (3.55)	7.97 (4.61)	$t_{42} = -1.299$	0.201	0.391
Duration of epilepsy (years)	6.18 (3.79)	5.67 (4.10)	$t_{42} = 0.420$	0.676	0.127
Seizure frequency past 12 months (p/week)[b]	3.31 (8.66)	2.12 (8.50)	$t_{42} = 0.460$	0.648	0.139
AED no.	1.41 (1.14)	1.18 (0.73)	$t_{42} = 0.786$	0.436	0.237
GASE scale	2.81 (1.69)	2.29 (1.35)	$t_{42} = 1.110$	0.274	0.339

GGE, genetic generalized epilepsy; TLE, temporal lobe epilepsy; AED, antiepileptic drug; GASE, Global Assessment of Severity of Epilepsy scale. All tests were two-tailed.
[a] Effect sizes estimates are Cohen's d (0.3 = small, 0.5 = medium, 0.8 = large).
[b] Average number of seizures the child experienced each week, over the past 12 months.

3.6. Correlations between POFA scores, demographic variables, and IQ in children with epilepsy

Correlations between age at testing, SES, and total FEP accuracy on the POFA were not significant for children with GGE, TLE, or the pooled epilepsy group (see supplemental tables). FSIQ was significantly related to total FEP accuracy in children with GGE, but not among children with TLE.

3.7. Epilepsy variables and FEP

3.7.1. Correlations between epilepsy variables and POFA

For children with GGE, there were no significant correlations between total FEP accuracy and epilepsy variables (i.e., age of seizure onset, duration of epilepsy, seizure frequency, epilepsy severity, number of AEDs). For children with TLE, younger age of seizure onset ($N = 22$, $rho = 0.493$, $p = 0.020$) and longer duration of epilepsy ($N = 22$, $rho = -0.451$, $p = 0.035$) were moderately correlated with reduced total FEP accuracy, but fell short of significance after Bonferroni correction was applied. As such, groups were collapsed to examine correlations for the overall group [40]. For the pooled epilepsy group, younger age of seizure onset ($N = 44$, $rho = 0.368$, $p = 0.014$) was correlated with reduced FEP, but fell short of significance after statistical corrections were applied (see supplemental tables).

3.7.2. Side of seizure focus and POFA scores

Descriptive statistics for FEP scores in children with LTLE and RTLE are presented in supplemental tables. There were no significant differences between the group with LTLE and group with RTLE in identification of any emotion or total FEP accuracy (see supplemental tables).

3.7.3. Surgical status and POFA scores

Descriptive statistics for FEP scores in children with TLE who had undergone surgery (postsurgery) or who had not undergone surgery (presurgery) are presented in supplemental tables. Pre- and postsurgery groups did not differ significantly from each other in total FEP accuracy or in any specific emotions (see supplemental tables).

4. Discussion

The primary aim of this study was to examine facial emotional perception (FEP) in children with GGE and TLE and its relationship to everyday social competence. Findings revealed significant overall FEP impairments not only in children (8 to 16 years old) with TLE, but also in children with GGE compared to controls. The magnitude of FEP impairments was comparable in the two epilepsy groups; however, more detailed analysis revealed emotion specific patterns of impairments in each group. While children with GGE were impaired in identifying anger and disgust, children with TLE were impaired in sadness and disgust, compared to controls. Neither group performed significantly below controls for happy, fearful or neutral faces. Contrary to expectations, total FEP accuracy was not significantly correlated with social competence, which was significantly reduced relative to controls in both epilepsy groups. Together, these findings provide novel insight into the magnitude and pattern of FEP impairments in children with GGE and TLE and highlight the need for further research to examine the psychosocial correlates of FEP impairment in these patient groups.

To our knowledge, this is the first study to examine FEP abilities in children with GGE. Our findings have shown, for the first time, that children with GGE have significant impairments accurately identifying and labeling emotional expressions on faces, which are comparable in size

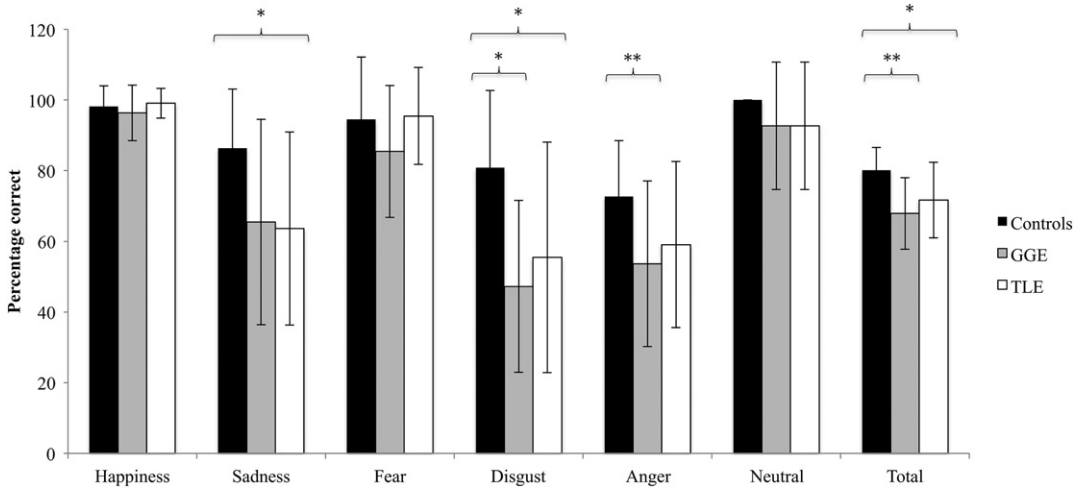

Fig. 1. Mean percentage correctly recognized facial emotions for all participant groups on the Pictures of Facial Affect (POFA) task. Error bars represent standard deviations. Significant between group differences: $^{*}p < 0.05$, $^{**}p < 0.01$.

to impairments found among children with TLE. This is important, as GGE is a common form of epilepsy in childhood [46,47], yet FEP impairments have not been studied in this patient population until now, and social cognitive deficits remain undetected and untreated in routine clinical care. We also found that children with GGE had deficits recognizing some facial expressions of emotion but not others, and the pattern of impairment was comparable to adults with GGE for whom impairments have been documented in anger and disgust, but not in happy, sad, fearful, or neutral faces [8]. For children with TLE, prior findings regarding the pattern of emotional impairments have been mixed, and our findings are consistent with one prior study [10] but deviate from another [9]. Inconsistent findings may relate to heterogeneity of the groups with TLE included in past studies, such as differing epilepsy characteristics, age of participants at testing, as well as varying sample sizes. Interestingly, both epilepsy groups were impaired in recognizing the emotion of disgust, which develops later than other emotions in which deficits were not observed (e.g., happiness, fear) [18]. It is possible that the difference between children with epilepsy and controls represents a delay in the development of recognizing this emotion; however, only a longitudinal study could address the issue of delayed vs. permanent impairment adequately. Given the literature on FEP in children with epilepsy is still in its infancy, further research (including longitudinal studies) would help to clarify these results.

A secondary aim of this study was to examine whether epilepsy variables related to FEP accuracy in children with GGE or TLE. We found no significant correlations between epilepsy variables and FEP in either epilepsy group. Nevertheless, moderate sized correlations were observed between earlier age of seizure onset, longer duration of epilepsy, and reduced total FEP accuracy in our group with TLE, which fell short of significance after statistical corrections were applied. These findings are consistent with prior empirical studies that have found significant relationships between younger age of seizure onset, longer duration of epilepsy and reduced FEP in children [9] and adults [48] with TLE. Thus, lack of significant findings in our study may reflect limited power. Further research is needed to examine whether epilepsy variables relate to FEP impairment in children with GGE, as this was the first study to examine such correlations, and identification of clinical markers may assist with detection and screening procedures.

We examined whether side of seizure focus or surgical status affected FEP impairments in our TLE group. Our results revealed comparable FEP performance (overall and in each emotion) in (i) children with LTLE and RTLE, consistent with past child studies [9,11], and (ii) pre- and postsurgery patients, consistent with longitudinal studies of children [10] and adults with TLE [49,50], and two recent systematic reviews of FEP in adults with TLE [51] and adults with focal epilepsy more broadly [24]. Together, these findings suggest that screening for FEP difficulties may be important in all subgroups of children with TLE, regardless of side of seizure focus or surgical status.

Unexpectedly, we found no significant relationship between overall FEP impairment and social competence problems in children with TLE or GGE. This is contrary to our hypotheses and to two converging theoretical models of social competence in children with epilepsy, children with genetic or acquired neurodevelopmental disorders, and typically developing children, which purport a relationship between social cognition and social competence [35,52]. There are several possible explanations for these findings. First, we only examined correlations between social competence and total FEP accuracy; we did not examine correlations for specific emotions or subgroups of children with TLE (i.e., LTLE/RTLE), as we wanted to limit the number of statistical tests performed. This may be important, as the only other study to examine the relationship between FEP and social outcomes in children with epilepsy found that accuracy at identifying fearful faces was related to social problems (CBCL Social Problems subscale [25]) in children with RTLE, but not LTLE [9]. A similar emotion-specific relationship has been observed in children with attention-deficit/hyperactivity disorder (ADHD): impaired anger recognition correlated with more interpersonal problems (on the Inventory of Interpersonal Problems [53]) [54]. Lack of significant correlations may also relate to the scales of social competence that we used and/or failure to measure broader aspects of psychosocial functioning, which have been found to relate to FEP impairments in other clinical groups. For instance, FEP deficits were related to antisocial behavior in children with conduct problems (on the Inventory of Callous-Unemotional traits [55]) [56] and interpersonal behavioral problems in children with ADHD [54]. Finally, it is possible that FEP is not directly related to social competence in children with epilepsy and that associations between social cognition and social competence are limited to higher order social cognitive skills, such as ToM [57,58]. Further research is needed to examine relationships between FEP impairments and social, emotional, and behavioral functioning in children with epilepsy, as understanding the functional implications of FEP difficulties is likely to assist with development of appropriate screening and treatment measures.

The current findings have important clinical implications for detecting and treating emotion recognition and social impairments in children with epilepsy. First, routine neuropsychological testing in pediatric epilepsy should include measures of FEP and social functioning. Currently, assessments focus primarily on general cognitive skills, such as IQ and memory [59], which fails to consider the psychosocial aspects of epilepsy. At present, tailored assessments for social cognition in epilepsy do not exist, but as research progresses specialized screening tools may become available. In the interim, we recommend that clinicians employ standardized tests, such as the facial emotion recognition subtest from the Social Perception subscale of the Developmental NEuroPSYchological Assessment-Second Edition (NEPSY-II), a widely employed and validated neuropsychological instrument [60], as well as rating inventories to assess broader aspects of social functioning, such as the SRS [38] or CBCL [25]. To our knowledge, no interventions exist to target underlying emotional processing deficits and social impairments in children with epilepsy. Such interventions are needed and should be prioritized in future work. Finally, increased knowledge and awareness of FEP and social impairments among clinicians working with children with epilepsy may increase detection and referral for psychosocial assessment and support.

4.1. Limitations

Limitations of the current study include the modest sample size, reliance on correlational analyses and use of parent-rated measures of social competence, which do not provide information about children's subjective social experiences. We did not examine correlations between specific emotions and social competence, which may be important, as emotion-specific abilities have been found to relate to social problems [9], interpersonal behavior problems [54], and antisocial behavior [56] in children with epilepsy and other neurodevelopmental and behavioral disorders. Failure to find significant differences between epilepsy groups and controls on certain emotions may have been due to a lack of power and/or a lack of sensitivity of the FEP measure that we used (the POFA [33]), as several emotions bordered on significant while others showed a ceiling effect. The POFA is a widely validated test that assesses FEP, however, the version that we employed presents facial emotions at maximum intensity and may have lacked sensitivity to detect more subtle deficits in facial emotion recognition [33]. This has also been a limitation of prior FEP studies in children with epilepsy, which have similarly used tasks that present emotions at a single, maximum valence [9–11]. Nevertheless, newer FEP batteries have been developed for children that present facial emotions at different valences (i.e., 75%, 50%, 25% intensity): the national institute of mental health child emotional faces picture set (NIMH-ChEFS) [61] and the animated full facial expression comprehension test (AFFECT) [23] are two such tasks that have been validated among children with [62,63] and without [23,61] developmental and psychological conditions. These tasks may be beneficial to employ in future research, and may provide clarity about which

emotions are impaired in epilepsy groups. Interestingly, the correlation between IQ and overall FEP accuracy was significant among children with GGE, but not significant in children with TLE; IQ was significantly reduced in children with GGE relative to children with TLE and controls. In addition, while IQ of children with GGE was low average to average, IQ of children with TLE was in an average range. Previous studies have found a significant relationship between IQ and overall FEP accuracy among children with epilepsy and low average IQ [10], but no significant relationship among children with epilepsy with average to high average IQ scores [64]. Hence, a different pattern of correlations found in our study could be related to between group differences in IQ. Given the limited number of studies conducted so far, the relationship between FEP and IQ requires further investigation among children with epilepsy, including those with and without IQ scores falling in a low average to impaired range. Understanding these relationships will provide a more holistic picture of the social and cognitive profiles of children with epilepsy, assisting with neuropsychological evaluations conducted in routine clinical care. Finally, use of a convenience sample to recruit control children may have added an undetected source of bias to results. While controls did not differ from children with epilepsy in age, gender or SES, they may have differed on environmental variables (e.g., family stress, parental anxiety, social stigma, and isolation) that potentially affect FEP accuracy and performance. We did not measure environmental contributors to FEP in the current study, as we focused on clinical correlates of FEP, but environmental factors are likely to contribute to FEP development in this group and are important to examine.

5. Conclusion

This study has shown that children with GGE and TLE have overall impairments recognizing emotional expressions on faces and reduced social competence compared to typically developing peers. The findings provide novel information that can be used to inform screening and treatment procedures for these groups. Screening for FEP and social impairments in children with epilepsy may help clinicians identify children who would benefit from psychosocial support. Better detection and early intervention for these difficulties may improve social outcomes in this group. At present, there are no evidence-based interventions designed specifically to address social impairments in children with epilepsy. It is unclear whether interventions developed for other clinical populations would be beneficial or whether tailored interventions need to be developed for this group. Identifying effective treatments should be prioritized in future work.

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Declarations of interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.yebeh.2019.04.054.

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