Social cognition in frontal lobe epilepsy

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Abstract

This study investigated the social cognitive functioning of patients with frontal lobe epilepsy (FLE), using a range of procedures that have shown impairments in patients following focal prefrontal brain lesions. Fourteen participants with FLE were compared with 14 healthy controls on story tests of theory of mind (ToM), faux pas appreciation, mental and physical state cartoon humor appreciation, facial emotional recognition, and the ability to perceive eye gaze expression. They were not impaired on story tests of ToM and showed only a trend toward impairment on a test of faux pas appreciation. They were impaired on humor appreciation, with both mental and physical state cartoons, and on their recognition of facial emotion and perception of eye gaze expression. Hence the patients with FLE exhibited impairments on tests of social cognition following a distinct pattern, with relatively preserved ToM, but impaired humor appreciation and ability to detect emotional expression.

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1. Introduction

Despite recent progress in the identification and classification of frontal lobe seizures, less is known about the clinical characteristics of frontal lobe epilepsy (FLE) than, for example, epilepsy associated with the temporal lobes. This is despite the fact that frontal lobe seizures represent the second most common type of seizure reported in surgical intervention in epilepsy, with FLE estimated to represent about 15% of the patients with pharmacoresistant epilepsies [1].

There have been few investigations of the neuropsychological and behavioral characteristics of FLE. Intellectual functioning appears to be approximately normal [2–4] and memory is not impaired to any great extent [5,6]. Executive functioning is impaired as indicated by an early study by Milner [3,4] using the Wisconsin Card Sorting Test (WCST), suggesting deficits in mental flexibility characterized by increases in perseverative errors. Executive and attentional functioning has also been investigated using large batteries of tests, with a publication by Helmstaedter et al. [7] showing impairment in response inhibition, psychomotor speed, and attention, and another study by Upton and Thompson [8] showing specific impairments on the Stroop [9], Trail Making [10], 20 Questions [11], and Cost Estimation [12] tests. Generally, such investigations have shown relatively mild executive functioning impairments, less severe than those commonly found with frontal neurosurgical lesions [13].

These mild executive functioning impairments may be accompanied by personality and emotional changes, frequently observed in such patients, in some instances

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producing behavioral dysfunction. This might be expected, given the involvement of the prefrontal cortex in social cognitive and emotional functioning. Neuroanatomically, the site of the seizure focus in FLE can be quite diverse, with widespread, bilateral, and rapidly propagating epileptic activity [7] potentially affecting neurocognitive functions served by the prefrontal cortex more globally. While the dorsolateral cortex is known to be involved in executive functions, such as those related to reasoning, abstract thinking, and problem solving, the orbitofrontal cortex has been implicated in specifically emotion-related interpersonal behavior and emotion perception [14–16]. The medial frontal cortex has been associated with theory of mind (ToM), affective regulation, emotional processing, and motivation [17,18]. Hence, damage to the prefrontal cortex potentially results in multifaceted impairments in interpersonal behavior [19]. Behavioral changes noted following prefrontal cortical brain damage include insensitivity to social cues, egocentrism, indifference to the opinions of others, a tendency to exhibit inappropriate affect, and social withdrawal.

Those aspects of frontal lobe functioning that come under the umbrella term social cognition have not been extensively investigated in FLE. A preliminary study by Corcoran [20] reported data from five patients with right frontal or frontotemporal foci (RF/FT), three people with left frontal or frontotemporal foci (LF/FT), and three people with bilateral frontal foci or damage (BF). Those in the RF/FT group were impaired relative to controls on a hinting task [21] that required participants to interpret the true intention of a story character who drops a heavy hint. The impairment is reported to be independent of group differences in IQ. Exner et al. [22] explored emotion perception conceptualization using a sorting task, in which patients had to sort photographs of faces according to emotional expressions, and also a paired associate learning task, in which the stimuli were faces with distinct emotional expressions, the object being to learn pairs of these stimuli. This showed impairments in patients with FLE relative to control participants, the deficits similar in magnitude to those found in patients with temporal lobe epilepsy (TLE). However, there was a large difference in intellectual functioning between the patients with FLE and the controls, and in the absence of an intelligence quotient (IQ)-matched control group it is not clear whether the impairment on this task was a more specific feature or due to their relatively lower intelligence.

The current study was designed to explore social cognitive and emotional functioning in FLE using a series of tests that have been sensitive to impairments following prefrontal cortical lesions. The neuropsychological procedures were selected to cover the main features of social cognition in an experimental fashion, incorporating the following five areas:

1. Theory of mind (ToM): This refers to the awareness of the likely content of the minds of other people, useful in interpreting people and guiding social activity [23].

Prefrontal cortical lesions have been shown consistently to impair this function [19,24–26]. Neuroimaging studies have implicated either the medial [27,28] or orbital prefrontal cortex in ToM functioning [29]. In patients with brain lesions, this function has been tested by presenting stories that require understanding of the thought and intentions of the characters and testing for comprehension (e.g., [25,30]).

2. Faux pas: This occurs when a person makes a remark he or she should not have made, not realizing at the time of utterance that he or she should not have made the remark, as it was perceived as hurtful, awkward, or insulting. The ability to detect faux pas tends to have developed by 9 or 10 years of age and is impaired in high-functioning autism [31]. It has also been found to be impaired in patients with bilateral orbitofrontal lesions by Stone et al. [26].

3. Humor: The ability to appreciate humor is an important component of social interaction, and this ability has been associated specifically with frontal lobe function. For example, Shammi and Stuss [32] found that patients with right frontal lesions show impairment on tests of humor. Also, neuroimaging studies have demonstrated tasks requiring appreciation of humor to activate the prefrontal cortex [27,33]. This study used a pictorial or cartoon method that requires an understanding of the thoughts of individual characters depicted in the cartoon, an approach more weighted to everyday social understanding that involves the movement and action of people. Cartoons can be used to investigate two types of humor: humor related to mental state representations, for example, in which a character demonstrates some misunderstanding and this has to be realized to appreciate the joke, and humor related to physical anomalies or violation of social norms. Appreciation of cartoons that invoke mental state representations has been shown to be impaired with right hemisphere lesions [30].

4. Recognition of emotion: A large component of social interaction involves recognition and interpretation of nonverbal information. Faces provide clues to the states of mind of other people, and individual emotions have distinct facial expressions. Evidence for the role of the prefrontal cortex in facial emotion expression comes from nonhuman primate research [34], neuroimaging [35,36], and brain lesion [15,16,37,38] studies, and in such studies the ventral prefrontal cortex appears to be implicated in emotion perception. In one method of assessing recognition of facial emotion, full-face photographs are used to depict basic emotions [39]; this is the technique used in the current study.

5. Inferring mental states and emotion from gaze expression: The mental state and emotional responses of other people can be inferred by inspecting the eyes of a person. This has been tested by requiring a participant to choose appropriate terms to describe what a person is “thinking” or “feeling” based on seeing a photograph of the eyes only. This task has so far been validated on patients
with high-functioning autism and Asperger’s syndrome, showing significant impairment [40]. It has also indicated impairment in patients with frontal variant frontotemporal dementia, the extent of deficit correlating with ventromedial frontal damage [41].

A series of tasks that measured these aspects were administered to persons with well-characterized FLE, who had undergone detailed neurophysiological investigations and magnetic resonance imaging (MRI). Because specific brain abnormalities are not always observed through structural neuroimaging in FLE, an additional inclusion criterion was that the patient had to have a videoelectroencephalogram (EEG) abnormality indicating a frontal focus. This had to be combined with either frontal seizure semiology or an identified frontal structural abnormality. In addition, the patients were high-functioning, that is, their IQ had to be above 79, hence enabling the measures of social cognition to be sufficiently sensitive to detect impairment. The patients were selected as a group to be not statistically different from the controls in premorbid intellectual functioning. Finally, the patients were given a broader neuropsychological assessment, including tests of memory and executive functioning. The latter was to test whether putative social cognition deficits would be similar in magnitude or greater than the executive dysfunction found in FLE.

2. Methods

2.1. Participants

Fourteen patients with FLE were recruited for the study, taken from cases diagnosed over a 20-month period in a specialist epilepsy unit at King’s College Hospital, London, UK. Most had been referred for presurgical evaluation of intractable epilepsy of presumed frontal lobe origin. To be included in the study, patients needed to meet two of the following three criteria: (1) interictal or ictal EEG evidence that clearly indicated onset in the frontal lobes, from either scalp recordings or intracranial EEG; (2) a seizure semiology consistent with onset in the frontal lobes; (3) an epileptogenic lesion in the frontal lobes identified using MRI. Exclusion criteria were: (1) either an epileptogenic focus or radiological evidence of dysfunction outside of the frontal regions; (2) history of major psychiatric disorder (e.g., depression or psychosis); and (3) an estimated premorbid IQ below 80. In addition, all patients included in the study had been in UK mainstream education. All patients had undergone a neurological examination and EEG investigations using video electromyography. All but two patients had undergone structural MRI. Lateralization and localization were based on lesion site as determined by MRI (where an identifiable lesion was present) and EEG. In no case were the MRI and EEG data in conflict. On this basis, eight patients were classified as having left frontal and five right frontal onset. One patient had bilateral seizure foci. Three patients had PET scans and another a SPECT scan, all consistent with the suggested lateralization. It was possible to localize the abnormality within the prefrontal cortex in nine patients, six patients with medial and three with dorsolateral abnormalities. No patients were found to have orbitofrontal foci. The mean age at epilepsy onset was 11.8 years (SD = 8.55).

The patients were compared with 14 healthy control participants, included if they had no history of neurological or psychiatric disorder. The two groups were comparable with respect to age, sex ratio, years of education (high school leaving age minus 5 years, with additional years in further education added on), and premorbid full-scale IQ (FSIQ) as estimated by the Wechsler Test of Adult Reading—UK Adaptation (WTAR) [42] (see Table 1). There were no significant differences between the groups on these variables (all independent t tests, \( P > 0.05 \)).

2.2. Background neuropsychological functioning

A background neuropsychological test battery was used to measure intellectual, memory, and executive functioning in the patients and control participants.

2.2.1. Intelligence

Intelligence was measured using the Wechsler Abbreviated Scale for Intelligence (WASI) [43], providing measures of FSIQ, Verbal IQ (VIQ), and Performance IQ (PIQ).

2.2.2. Memory

Verbal long-term memory was measured using the Wechsler Memory Scale III [44] Logical Memory subtest (with Story A presented once and Story B presented twice). Visual memory was tested using the WMS-III Visual Reproduction subtest.

2.2.3. Executive functioning

The Trail Making [10] and Brixton [45] tests were used to measure sequencing and mental flexibility, the Hayling Test [45] to measure generativity and response inhibition, and the Controlled Oral Word Association Test (COWAT), with F, A, and S as the letter cues [46], to measure generativity.

2.3. Social cognition

2.3.1. Story task

The stimuli consisted of 16 short stories, the same as those described by Happé et al. [30,47]. Half of these were stories...
invoking ToM and the other half (non-ToM) did not (see the Appendix for examples). The ToM stories involved interaction between people and were split into four types, involving either double bluff, mistakes, persuasion, or white lies, with two of each type. Each ToM story was followed by a question testing ability to make inferences about mental states, usually the speaker’s/actor’s intentions. The non-ToM stories also involved people, but in this case the test questions required the participants to make inferences in which the mental states of the characters were not relevant, for example about physical causation. The main procedure for administration followed that of Happé et al. [30,47], with the participant reading the story on a single page. In our version, to reduce the memory load of the task, participants were allowed to view this sheet when they answered the question. The standard scoring criteria of Happé et al. [30,47] were applied. Two points were awarded for a full and explicitly correct answer, one for a partial or implicit answer, and zero for an incorrect answer.

2.3.2. Faux pas task

The faux pas task stimuli consisted of 20 stories as described by Gregory et al. [41] based on the procedure used by Stone et al. [48], half of which contained a social faux pas and half of which did not. The spelling and wording were adapted slightly from the Gregory et al. [41] material to make them suitable for UK participants (see the Appendix). The stories were presented one at a time, each on a single page. The story text was placed in front of the participants and read aloud by the experimenter, who then asked questions about the story:

1. Did anyone say something he or she shouldn’t have said or something awkward? If they answered “yes” they were asked:
2. Who said something he or she shouldn’t have said or something awkward?
3. Why shouldn’t he or she have said it or why was it awkward?
4. Why do you think he or she said it? This question was to check for understanding that the faux pas was unintentional.
5. Did X know that Y? Again, this was to test whether they person realized that the faux pas was unintentional.
6. How did X feel? This was a test of empathy for the story characters.

Questions 7 and 8 were control questions to check for understanding of the details of the story.

Questions 2–6 were asked only if the participant detected a faux pas. If not, the experimenter skipped to 7 and 8 (the control questions). The scoring system used by Stone et al. [48] was used.

2.3.3. Cartoon humor tasks

The stimuli consisted of 12 single-frame cartoons taken from popular magazines (e.g., New Yorker) described by Happé et al. [30,47]. They formed two conditions: ToM cartoons (MS—mental state), in which the humor depended on what a character mistakenly thought or did not know, and non-ToM cartoons (PS—physical state), in which the humor did not involve a character’s false belief or ignorance but rather a physical anomaly or violation of a social norm (see the Appendix). Four in each set show facial expressions; three in each set include captions which were read aloud to participants. The administration followed that of Happé et al. [30,47], with the cartoons shown one at a time and left in front of the participant until he or she completed the answer. The test question was: Why is the cartoon funny? The standard scoring criteria of Happé et al. [30] were applied. The participants were able to score a maximum of 3 points for each of the cartoons, leading to a maximum score of 18 for each of the conditions (MS and PS). Three points were given for a full and explicit explanation, two for a partial/implicit explanation, and one for reference to relevant parts of the cartoon without further explanation. Irrelevant, incorrect, or “don’t know” answers were scored 0.

2.3.4. Recognition of facial emotion

The participants were presented with 12 photographs of actors displaying one of six basic facial emotions [39], individually in a pseudo-random order. The emotions were sadness, anger, fear, disgust, surprise, and happiness (two of each emotion, one portrayed by a man and the other by a woman). The photographs were surrounded by a choice of the verbal labels of the six emotions arranged pseudo-randomly. The participants were asked to pick the appropriate verbal label to describe what the actor in the photograph was feeling. One point was awarded for each correct choice; the maximum score was 12.

2.3.5. The eyes task

The stimuli consisted of 36 photographs of the eye area of the faces of different actors using the same material as Baron-Cohen et al. [40] (see the Appendix). These were presented one at a time in a fixed pseudo-random order. The eye areas depicted complex mental states, defined by Baron-Cohen et al. [40] as those that involve attribution of a belief or intention to the person. Each pair of eyes was surrounded by a choice of four verbal labels from which the participant had to pick one to match the expression in the eyes. They were asked to pick the one that best described what the person was “thinking or feeling.” A glossary of complex MS words was provided which participants were advised they could consult to determine the meaning of any words they were unsure of or ask the experimenter to read the definition aloud. One point was awarded for each correct choice; the maximum score was 36.

2.3.6. Reliability of ratings

For the stories, cartoons, and faux pas tasks, the experimenter had to rate the verbal response of the participants
to particular questions. As this rating could be influenced by the individual manner in which the scoring criteria were implemented, it was necessary to check the reliability of this approach. For each test, the responses of eight participants with FLE and eight controls were marked again by a second person, blind to group membership. By use of a two-way random effects model, the single measure intraclass correlations for the total scores were computed. For the total score on the ToM stories this was 0.94 (95% confidence interval (CI): lower = 0.85, upper = 0.98). For the non-ToM stories it was 0.91 (95% CI: lower = 0.77, upper = 0.97). For the MS cartoons it was 0.94 (95% CI: lower = 0.85, upper = 0.98), and for the PS cartoons, 0.91 (95% CI: lower = 0.77, upper = 0.97). For the faux pas task the coefficient was 0.94 (95% CI: lower = 0.84, upper = 0.98). There was 100% agreement on the total number of “hits” and “correct rejects” and on the total score for control questions. This indicated that there were high degrees of consistency in the scoring between the two raters for the different measures.

### Table 2

Intellectual Quotients (IQs) measured using the Wechsler Abbreviated Scale for Intelligence (WASI) on patients with frontal lobe epilepsy (FLE) and control participants

<table>
<thead>
<tr>
<th></th>
<th>Patients with FLE</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal IQ</td>
<td>95.57 (10.78) a</td>
<td>101.14 (16.47)</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>97.86 (13.13)</td>
<td>98.64 (14.78)</td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>96.57 (11.92)</td>
<td>100.29 (16.86)</td>
</tr>
</tbody>
</table>

*a Mean (SD).

### Table 3

Memory, executive, and social cognition results for patients with FLE and control participants

<table>
<thead>
<tr>
<th></th>
<th>FLE</th>
<th>Controls</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logical Memory</td>
<td>38.07 (7.40) a</td>
<td>37.71 (10.17)</td>
<td>0.916</td>
</tr>
<tr>
<td>Visual Reproduction</td>
<td>83.14 (12.94)</td>
<td>85.79 (10.31)</td>
<td>0.555</td>
</tr>
<tr>
<td>Executive Function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trail Making Test A, s</td>
<td>37.00 (12.64)</td>
<td>26.07 (8.97)</td>
<td>0.014</td>
</tr>
<tr>
<td>Trail Making Test B, s</td>
<td>86.79 (58.62)</td>
<td>70.21 (44.94)</td>
<td>0.409</td>
</tr>
<tr>
<td>Brixton Test, error score</td>
<td>17.21 (7.11)</td>
<td>18.50 (11.69)</td>
<td>0.728</td>
</tr>
<tr>
<td>Hayling 1, s</td>
<td>14.36 (15.98)</td>
<td>3.57 (2.41)</td>
<td>0.026</td>
</tr>
<tr>
<td>Hayling 2, s</td>
<td>47.64 (24.51)</td>
<td>46.93 (23.79)</td>
<td>0.938</td>
</tr>
<tr>
<td>Hayling 2, errors</td>
<td>9.21 (7.51)</td>
<td>4.36 (3.59)</td>
<td>0.042</td>
</tr>
<tr>
<td>Hayling Overall Scaled Score</td>
<td>4.71 (2.05)</td>
<td>6.00 (0.68)</td>
<td>0.041</td>
</tr>
<tr>
<td>Verbal Fluency Total Words</td>
<td>30.57 (7.91)</td>
<td>46.36 (15.39)</td>
<td>0.002</td>
</tr>
<tr>
<td>Social cognitive function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theory-of-mind stories (0–16)</td>
<td>11.35 (3.59)</td>
<td>12.79 (2.86)</td>
<td>0.549</td>
</tr>
<tr>
<td>Non-theory-of-mind stories (0–16)</td>
<td>12.21 (2.42)</td>
<td>12.21 (4.06)</td>
<td>0.729</td>
</tr>
<tr>
<td>Faux pas hits (0–10)</td>
<td>9.71 (0.61)</td>
<td>9.86 (0.36)</td>
<td>0.734</td>
</tr>
<tr>
<td>Faux pas correct rejections (0–10)</td>
<td>9.07 (1.38)</td>
<td>9.21 (1.86)</td>
<td>0.571</td>
</tr>
<tr>
<td>Faux pas correct person (0–10)</td>
<td>9.43 (0.76)</td>
<td>9.86 (0.36)</td>
<td>0.178</td>
</tr>
<tr>
<td>Faux pas composite score (0–40)</td>
<td>0.92 (0.08)</td>
<td>0.98 (0.04)</td>
<td>0.056</td>
</tr>
<tr>
<td>Faux pas memory/comprehension</td>
<td>39.86 (0.00)</td>
<td>40.00 (0.00)</td>
<td>No analysis</td>
</tr>
<tr>
<td>Mental state cartoon (0–18)</td>
<td>10.42 (4.36)</td>
<td>14.00 (3.28)</td>
<td>0.014</td>
</tr>
<tr>
<td>Physical state cartoon (0–18)</td>
<td>9.00 (3.72)</td>
<td>12.21 (3.31)</td>
<td>0.014</td>
</tr>
<tr>
<td>Face expression judgement (0–12)</td>
<td>8.57 (1.83)</td>
<td>11.14 (0.77)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Eyes mental state judgement (0–36)</td>
<td>22.79 (6.02)</td>
<td>27.86 (3.78)</td>
<td>0.014</td>
</tr>
</tbody>
</table>

*a Mean (SD). Ranges given where appropriate.

3. **Results**

### 3.1. Analysis

For tests where there were single measures for comparison, t tests were used to compare the two groups. Where there were related measures, a general linear model with repeated measures was used in the analysis, with group (controls, patients with FLE) as a between-subject factor and the conditions as a within-subject factor. For non-parametrically distributed data, Mann–Whitney tests were used to compare the groups on each separate measure.

### 3.2. Background neuropsychological functioning

#### 3.2.1. Intelligence

No significant differences were found between the groups in VIQ (t(26) = −1.11, P = 0.299), PIQ (t(26) = 0.42, P = 0.883), or FSIQ (t(26) = 0.67, P = 0.507) (see Table 2).

#### 3.2.2. Memory

Likewise, no significant differences were found between the groups on memory, including Logical Memory (t(26) = 0.11, P = 0.916) and Visual Reproduction (t(26) = 0.59, P = 0.555) (see Table 3).

#### 3.2.3. Executive functioning

As predicted, there were differences between the groups on tests of executive functioning, but these did not occur on all measures (see Table 3). On Part A of the Trail Making

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Test, which measures sequencing, the FLE group was significantly slower ($t(26) = 2.64, P = 0.014$). However, there was no difference between the groups on Part B, measuring mental flexibility ($t(26) = 0.84, P = 0.409$). There was also no significant difference between the groups on the Brixton Spatial Anticipation Test ($t(26) = 0.35, P = 0.728$).

Hayling Test Section 1, which measures generativity, patients in the FLE group were significantly slower than the controls ($t(26) = 2.497, P = 0.026$). On Section 2, which measures response inhibition, there was no difference in response time ($t(26) = 0.078, P = 0.938$), but the patients made significantly more errors ($t(26) = 2.185, P = 0.042$). The patients also achieved a significantly lower overall scaled score on the Hayling Test ($t(26) = 2.22, P = 0.041$). The control group produced significantly more words than the FLE group on the Verbal Fluency (FAS) test ($t(26) = 3.41, P = 0.002$).

3.3. Social cognition

3.3.1. Story task

The total numbers of correct answers for the ToM and non-ToM story conditions were computed (see Table 3). In an analysis of the data, the main effects of neither group ($F(1,26) = 0.55, P = 0.549$) nor story type ($F(1,26) = 0.12, P = 0.729$) were significant. Additionally, the group by story type interaction was not significant ($F(1,26) = 3.07, P = 0.092$).

3.3.2. Faux pas task

The measures taken were the total number of times that a participant correctly detected a faux pas when it existed in a story (hits) and the total number of times a participant correctly indicated there was not a faux pas in a story (correct rejections). A composite score was also computed by dividing the total number of faux pas-related questions answered correctly on the faux pas stories by the total number of questions asked on the faux pas stories. This was used to control for the fact that if participants answered “No” to question 1 (Did someone say something he or she shouldn’t have said or something awkward?), they were asked no further questions on that story and so could not score anything other than zero. In addition, the number of times the faux pas was attributed to the correct person was recorded (i.e., the responses to Question 2: Who said something he or she shouldn’t have said or something awkward?). Finally, the total number of non-ToM (memory/comprehension) questions answered correctly was computed for both faux pas and control stories. There were no differences between the groups on the number of hits ($U = 90.00, P = 0.734$), correct rejections ($U = 85.50, P = 0.571$), or correct person ($U = 68.00, P = 0.178$). There was a trend toward the FLE group scoring lower than the control group on the composite score ($U = 56.00, P = 0.056$). Performance on the memory/comprehension questions was at the ceiling for the control group and fell short of the ceiling by only approximately two points in the FLE group.

Table 4
Numbers of patients with FLE and controls making at least one error on the two examples of the six different facial expressions of emotion on the recognition of facial emotion task*

<table>
<thead>
<tr>
<th></th>
<th>Patients with FLE</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anger</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Disgust</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Happiness</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Sadness</td>
<td>9**</td>
<td>0***</td>
</tr>
<tr>
<td>Fear</td>
<td>9</td>
<td>0***</td>
</tr>
<tr>
<td>Surprise</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* Sign test used to explore group differences.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

3.3.3. Cartoon task

The measures were total number of correct answers for the MS and PS conditions (see Table 3). A main effect for group was observed ($F(1,23) = 6.99, P = 0.014$), with the FLE group less accurate. There was also a main effect of cartoon type ($F(1,26) = 11.92, P = 0.002$), with participants finding the PS cartoons more difficult than the MS cartoons. The group by cartoon type interaction was not significant ($F(1,26) = 0.15, P = 0.704$).

3.3.4. Recognition of facial emotion

The scores on this test are listed in Table 3. The FLE group also scored significantly lower than the control group on the facial emotion recognition task ($t(26) = 4.851, P = 0.0001$). A breakdown of the errors on the different emotions is given in Table 4, with the data expressed in terms of the number of participants in each group making at least one error on the two trials for each emotion. This shows that the groups are well discriminated on anger, sadness, and fear, but not disgust, happiness, or surprise.

3.3.5. Eyes task

The number correct scores are listed in Table 3. The FLE group scored significantly lower than the control group ($t(21.88) = 2.67, P = 0.014$).

3.4. Effect sizes

To compare the size of the impairments across tests in the FLE group, the group mean $z$ scores were computed based on the control mean and SD. This showed that where deficits existed, they tended to be mild in nature, the exception being perception of emotional expression, for which there was substantial impairment, equivalent to approximately 3 SD (the main $z$ scores are shown in Fig. 1).

3.5. Correlations between social cognition tasks and executive function tasks

To examine the relationship between deficits on social cognition tasks and deficits on executive function tasks,
Pearson product moment correlations (or Spearman rank correlations in the case of the faux pas composite score) were calculated. All significant correlations were in the expected direction; i.e., poorer performance on one task was associated with poorer performance on the other. For the FLE group, there were no significant correlations. For the healthy control group, the verbal fluency (FAS) test was significantly correlated with the eyes task \( (r = 0.620, n = 14, P = 0.018) \) and with the PS cartoons \( (r = 0.536, n = 14, P = 0.048) \).

3.6. Correlations between social cognition and age of onset

To examine the relationship between social cognition and age at onset of epilepsy, Pearson product moment correlations (or Spearman rank correlations in the case of the faux pas data) were calculated. No significant correlations were found.

4. Discussion

This study compared the performance of patients with FLE, on a range of neuropsychological and social cognitive tasks, with that of a normal control group who did not differ statistically in age, education level, premorbid intelligence, or memory function. Mild impairments were observed in executive functioning, specifically in generativity, with mental flexibility and response inhibition spared. Social cognitive deficits were evident, and these again were on selected tests. The FLE group was found to be unimpaired on the ToM stories tasks, suggesting that verbal second-order ToM is intact in this patient group. There was a trend toward impairment on a more advanced test of ToM or social understanding, the faux pas task, this apparent on the composite score. On the humor appreciation task, those in the FLE group were impaired on both the MS and PS cartoons. They also showed a clear impairment in their facial emotional recognition performance and on a test that required inferring mental states and emotion from gaze expression.

Hence this study shows that not only do patients with FLE exhibit impairments in executive functioning, but they have deficits on some aspects of social cognition. Because the patients and controls did not differ in premorbid intelligence or memory, it is less likely that their deficits cannot be attributed to impairment in these aspects of functioning (although a larger sample size may be needed to determine this more fully). Nor were any correlations found between the patients’ deficits on executive functioning tasks and impairment on social cognition tasks. This study follows previous findings of impairments on hint perception in five patients with a right frontal or right frontotemporal EEG focus [20] and also Enxer et al. [22] who found impairments in facial perceptual conceptualization and paired associated learning using faces with emotional expressions.

The finding of specific impairments, rather than generalized deficits, mirrors the results of studies exploring executive dysfunction [7,13,49]. The lack of a global impairment in social cognition can be interpreted in various ways. One possibility is that the brain abnormality is regionally selective and is affecting only those aspects of social cognition that are supported by the impaired brain regions. A second possibility is that some aspects are more sensitive to impairment, perhaps those that reflect later development, although this does not seem to be supported by the most substantial deficits in facial emotional expression perception. Finally, it could be the case that the degree of impairment is dependent on differential test sensitivity. These factors can be explored by considering the social cognitive functioning of other brain-damaged patient groups and also whether the pattern of impairment concerning different aspects of social cognition varies between the brain regions implicated.

The absence of impairment in ToM as tested by the stories task contrasts with studies showing impairments in patients with right hemisphere damage due to stroke [30], and in adults with autism and with high-functioning autism [50,51]. However, Baron-Cohen et al. [52] found that while individuals with Asperger’s syndrome could pass first- and second-order tasks, they were impaired on a test of faux pas recognition. Also, there is evidence that the first- and second-order ToM abilities required by the procedure are understood at a relatively early age, by most normally developing children between the ages of 6 and 7, whereas the ability to understand faux pas develops later, between the ages of 9 and 11 years [52]. Patients in the FLE group were not impaired with respect to their ability to detect whether a faux pas had been committed or to attribute it to the correct story character, but there was a trend toward impairment on a composite score that included other questions examining their understanding of the faux pas. The current study is somewhat limited by the small sample size, so it is possible that a larger group of patients would have
shown significantly impaired faux pas. As a caveat, it is possible that a larger sample would have also been impaired on the ToM stories, because although there was no trend in this study, the current sample may have been less representative of FLE patients as a whole than a larger sample. Nevertheless, it may be that, in common with Asperger’s syndrome, the ability to detect faux pas is more susceptible to impairment, because of the later age of acquisition of this ability.

The study indicated that the FLE group showed less appreciation of humor, this applying to both humor requiring representation of mental states and humor dealing with detection of physical anomalies or violation of social norms. Functional neuroimaging studies suggest that humor appreciation is associated with activation of the medial prefrontal cortex [27,33]. Similar to the current study, Happé et al. [30] compared humor appreciation with mental and physical state cartoons in patients with left or right hemisphere lesions. They found impairments in patients with right hemisphere lesions, specifically relating to MS-type cartoons. Additionally, Shammi and Stuss [32] found that humor appreciation was impaired in patients with focal frontal lesions, with specific links to aspects of executive functioning, consistent with the notion that understanding a joke may involve a degree of problem solving, drawing on executive capacity [53]. This was not the case in the current study, with no association, for example, with mental flexibility. Individual patients, however, gave responses that were literal and concrete. For example, in the “children crossing” cartoon there is a road sign that reads “Children Crossing” and is illustrated with the silhouette of two children. Two identical children, in silhouette, are shown crossing the actual road in the cartoon. In answer to the question Why is it funny? most control subjects say that it is because one would not expect to see exactly what is shown on the sign. By contrast, one patient answered: “It must be in the States because it’s a left-hand drive car. They’re walking on the wrong side of the road; they should walk on the other side or they’ll be knocked down.” Such literal responding is commonly associated with frontal lobe damage [54].

Another factor is the affective aspect of humor, with full appreciation of humor involving the integration of cognition and emotions, the affective component possibly linked to ventral prefrontal cortical regions [33]. In the present study it was noted that even patients who “passed” on a cartoon by identifying the humorous element frequently manifested no amusement. After viewing the “children crossing” cartoon, one patient said “I don’t think it’s funny. What he sees on the sign he can see walking across the street. It’s not funny.” One way of following this up would be to ask participants to choose “the funny one” from a choice of cartoons or from joke punch lines. Another approach would be to measure affective response (laughing and smiling) or to take a precise measure of how funny the participant finds the joke on a Likert scale, prior to giving their explanation.

A clear impairment was found on the facial emotion perception task, and this test best discriminated the FLE group from the control participants. The result is consistent with Exner and colleagues [22] finding that FLE and TLE groups made significantly more errors than controls on an emotional conceptualization task in which participants had to sort 16 faces from the Ekman series according to emotion category. Previously, facial emotion recognition impairment has been demonstrated in patients with diffuse and discrete prefrontal brain lesions [15,37,38]. The test used here involved selecting verbal labels to match the facial emotion, a procedure that was previously found to be the most sensitive in detecting impairment in patients with prefrontal brain lesions [38]. Notably, patients in the FLE group were not impaired on all the emotions, the ones showing deficits being anger, fear, and sadness. Two of these emotions, namely, anger and fear, match the impairments most frequently found in a study of focal frontal lesions by Rowe et al. [38]. Faulty processing of these emotions is known to produce breakdowns in social communication in confrontational situations, as, for example, when anger provokes fear, which is misinterpreted as anger and so may cue an even more aggressive response.

The eyes task requires emotion perception, but is also described as a test of ToM because it depicts complex cognitive mental states, with the participant required to attribute a cognitive mental state, that is, a belief or intention, to the person depicted. By contrast, it is suggested [40] that the facial expressions depicted in the Ekman faces can be recognized purely as emotions. However, it is possible that the loading of the eyes task may be more toward direct emotional processing rather than abstract inference of mental state. It is noteworthy that all but one of the patients in this study who showed impairment on the eyes task also showed impairment on the Ekman faces task. There have been few studies using the eyes test in patients with brain damage, but studies have been conducted on patients with frontal variant fronto temporal dementia (fvFTD). Gregory et al. [41] found that although patients with fvFTD were impaired on the same eyes task and other ToM tasks, there were no correlations between the deficits. In keeping with this, Lough et al. [55] reported the case of a patient with fvFTD who was impaired on both first- and second-order false belief tasks but not on the eyes task. This might suggest that the emotion component, rather than ToM, is more highly related to the deficits found in both fvFTD and the current FLE groups.

In summary, this study shows that the FLE group had a particular pattern of impairment on tests of social cognitive functioning; hence, it can be concluded that the impairments found may translate into everyday difficulties in social situations, an aspect that needs to be explored further. It should be noted that this is a preliminary study, and a larger group of patients with FLE are needed to determine whether the current results can be generalized to FLE as a diagnostic category, although the current findings show sufficiently marked impairments to suggest that this might
be the case. Nevertheless, negative findings, in relation to ToM and faux pas, may not have been observed because of the small number of participants. A larger sample would enable the relationship between social cognitive functioning and location of seizure focus to be explored, for example, left versus right hemisphere differences. Additionally, patients with FLE need to be compared with other focal epilepsy patients, for example, TLE caused by mesiotemporal lobe sclerosis. It is possible that the impairments observed in the current study are not specific to FLE, and indeed this has been found to be the case for executive dysfunction, for example, as studied by Exner et al. [22].

This study shows in a preliminary fashion that high-functioning patients with FLE do have impairments in social cognition in addition to the mild impairments in executive functioning. The impairments are not in all aspects of social cognitive functioning, but affect humor appreciation and perception of emotional expression. The finding of social cognitive dysfunction is in keeping with the area of the brain implicated in such patients and also reports of behavioral disturbance. Nevertheless, in parallel with executive dysfunction, they appear to be mild or moderate in nature and not as severe as reported in patients with focal lesions. Future studies are needed to investigate the effects of the impairment on everyday function and whether they are increased through surgical treatment.

Appendix.

1. Example of theory-of-mind story

A burglar who has just robbed a shop is making a getaway. As he is running home, a policeman on his beat sees him drop his glove. He doesn’t know the man is a burglar, he just wants to tell him he has dropped his glove. But when the policeman shouts out to the burglar, ‘Hey, you! Stop!’, the burglar turns round, sees the policeman and gives himself up. He puts his hands up and admits that he did the break-in at the local shop.

Question: Why did the burglar do that?

2. Example of a nonmental story

A burglar is about to break into a jewelers’ shop. He skillfully picks the lock on the shop door. Carefully he crawls under the electronic detector beam. If he breaks this beam it will set off the alarm. Quietly he opens the door of the store room and sees the gems glittering. As he reaches out, however, he steps on something soft. He hears a screech, and something small and furry runs out past him, toward the shop door. Immediately the alarm sounds.

Question: Why did the alarm go off?

3. Example of faux pas task story

Jill had just moved into a new apartment. Jill went shopping and bought some new curtains for her bedroom. When she had just finished decorating the apartment her best friend Lisa came over. Jill gave her a tour of the apartment and asked “How do you like my bedroom?” “Those curtains are horrible,” Lisa said, “I hope you’re going to get some new ones.”

4. Example of mental state and non-mental state cartoon humor task

<table>
<thead>
<tr>
<th>Mental State</th>
<th>Non-Mental State</th>
</tr>
</thead>
<tbody>
<tr>
<td>“I give up Robert. What does have two horns, one eye and creeps?”</td>
<td>“looks like Wesselman’s hit on something interesting”</td>
</tr>
</tbody>
</table>
5. Example of photograph from the eyes task. In this example, the participant has to choose between the mental states reflective, aghast, irritated, and impatient.

References


