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The green-eyed monster and malicious joy: the neuroanatomical bases of envy and gloating (schadenfreude)

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Facing a protagonist's emotional mental state can trigger social emotions (or 'fortune of others' emotion), such as envy or gloating, which reflect one's assessment of the consequences of the other's fortune. Here we suggest that these social emotions are mediated by the mentalizing network. The present article explores the notion that the understanding of social competitive emotions is particularly impaired in patients with ventromedial (VM) prefrontal lesions. By manipulating a simple Theory of Mind (ToM) task, we tested the ability of patients with localized lesions to understand 'fortune of others' emotions: envy and gloating (schadenfreude). Patients were also assessed for their ability to recognize control physical and identification conditions. While envy is an example of a negative experience in the face of another's fortunes, gloat is thought to be a positive experience in the face of another's misfortune. Whereas in schadenfreude and envy the emotion of the self and the protagonist may be opposite, identification involves matching between the protagonist's and the observer's emotions. Patients with VM ($N = 10$) lesions (particularly in the right hemisphere), although showing intact performance on a basic first order ToM condition, and relatively preserved understanding of identification, did not recognize envy ($F[6,76] = 3.491$, $P = 0.004$) and gloating ($F[6,76] = 3.738$, $P = 0.003$). Impaired recognition of gloating involved additionally lesions in the inferior parietal lobule ($P = 0.001$). Furthermore, while patients with lesions in the left hemisphere were more impaired in recognizing gloating (a positive emotion), right hemisphere patients were more impaired in recognizing envy (a negative emotion), suggesting that the valence of these emotions may also be affected by the asymmetry of the lesion ($F[6,68] = 2.002$, $P = 0.011$). In addition, the ability to identify these emotions was related to perspective-taking abilities and ToM. We suggest that these results indicate that the mentalizing network including the VM has a fundamental role in mediating the understanding of competitive emotions such as envy and gloating.

Keywords: ventromedial prefrontal cortex; emotions; envy; gloating; schadenfreude

Abbreviations: CVA = cerebrovascular accident; PFC = Prefrontal cortex; TOM = Theory of Mind; VM = ventromedial

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Introduction

Social perception is a vital part of social life and involves recognition of emotions as well as mental state attributions (Adolphs, 2006). It has been suggested that the evolution of social understanding may have emerged partly from competitive situations in which resources are limited and understanding of competitors provides individuals with selective advantage (Hare *et al.*, 2001). In accordance with this, primates have been shown to exhibit sophisticated mentalizing abilities, predominantly in competitive situations (Byrne and Whiten, 1988; Tomasello *et al.*, 2003; Flombaum and Santos, 2005).

'Fortune of others' emotions

Competitive situations may involve, on the one hand, social emotions (such as gloating and envy) towards rivals, and identification with in-group members, on the other hand. Gloating and envy, which have been classified by some as 'fortune-of-others' emotions (Ortony *et al.*, 1990) depend on the implication of events for one's goal, when events in question always concern what happens to other people. These emotions involve two-person situations in which one's loss or gain depends on the other's gain. Envy is comprised of the wish to have another person's possession or success and/or the wish that the other person did not possess the desired characteristic or object (Parrott, 1991). On the other hand, when a person judges an event to be undesirable for another person and is pleased about it, we may describe that person as gloating (Ortony *et al*., 1990). This particular type of emotional reaction is also termed 'pleasure at another's misfortune' or *schadenfreude*, a German word literally denoting joy with the shame or misfortune of another (see, e.g. Ben-Ze'ev, 1992; Smith *et al*., 1996)—there is a similar term in Hebrew ('Simha La-aid') but no specific term in English; the closest is gloat ('gloating over someone's misfortune'). Moreover, it was recently shown that schadenfreude and envy are related emotions and that schadenfreude is frequently experienced towards individuals we envy (van Dijk *et al*., 2006). While envy is an example of a negative experience in the face of another's fortunes, gloat is thought to be a positive experience in the face of another's misfortune. While in schadenfreude and envy the emotion of the self and the protagonist may be opposite, identification involves matching between the protagonist's and the observer's emotions. It may be expressed in emotions such as pity, compassion and 'happy for' emotions (Ben-Zeev, 2001).

The mentalizing network and its role in envy and gloating

Although the neural correlates of basic emotions (for review, see Phan *et al*., 2002) and Theory of Mind (ToM) (Frith and Frith, 2006) have been extensively documented in the literature, the neuroantomical basis of social competitive emotions such as gloating and envy has never been examined before to the best of our knowledge.

One potential critical player in mediating these emotions is the ventromedial (VM) prefrontal cortex (PFC). The VM is comprised of the inferior frontal gyrus and the orbitofrontal and medial prefrontal gyrus within the PFC. The intimate connections of the VM prefrontal cortex to the anterior insula, temporal pole, inferior parietal lobe and amygdala place it in a suitable position to evaluate and regulate emerging information from the limbic system, to be used for inhibiting behaviour, regulating emotions and understanding complex social situations. Indeed, lesions in VM cortices result in a syndrome that is characterized by disinhibition, lack of tact and, in some cases, even 'acquired sociopathy' (Blair and Cipolotti, 2000; Tranel *et al*., 2002). Emotional and social impairments are frequently reported after damage to the PFC in humans, especially when the damage involves the orbitofrontal/ventromedial prefrontal cortex (Stuss and Benson, 1986; Elslinger and Damasio, 1985; Shamay-Tsoory *et al*., 2003; Mah *et al*., 2004). Clinical observations and experimental studies indicate that these patients fail to show regret (Camille *et al*., 2004) and develop a severe impairment in personal and social decision-making, despite intact intellectual abilities (Damasio *et al*., 1991). Attempts have been made to explain the behavioural deficits reported in patients with VM lesions in terms of impairment in emotion recognition (Hornak *et al*. 1996), lack of ToM (Stone *et al*., 1998; Rowe *et al*., 2001; Stuss *et al*., 2000), and impaired empathy (Eslinger *et al*., 1998; Shamay-Tsoory *et al*., 2003).

Since social emotions such as the 'fortune-of-others' emotions are predominantly experienced in social situations and involve social comparison, it is most likely that they involve mentalizing abilities and, thus, are mediated through the mentalizing network. While both neuroimaging (Fletcher *et al*., 1995; Goel *et al*., 1995; Gallagher *et al*., 2000) and lesion (Stone *et al*., 1998; Rowe *et al*., 2001; Stuss *et al*., 2001; Shamay-Tsoory *et al*., 2005) studies have illustrated a critical role for the medial PFC in ToM-related tasks, recent studies have questioned the unique role of the medial PFC in mentalizing (Bird *et al*., 2004), emphasizing the role of the temporo-parietal junction in reasoning about beliefs of others (Samson *et al*., 2005).

Moreover, linking mentalizing with the experience of competition, Decety *et al*. (2004) have shown that the medial PFC is activated more in competitive than in cooperative conditions. The authors reasoned that, in competitive situations, the opponent's upcoming behaviour is less predictable and may require additional mentalizing processing.

Taken together, it may be speculated that patients with VM damage may show a more pronounced impairment in understanding of competitive emotions, such as gloating and envy, than in understanding cooperative situations, such as identification.

One issue that may complicate the study of these emotions concerns the vagueness of the facial indices related to social emotions (Bauminger, 2004). In these emotions, one's own mental state is reflected vis-à-vis the reflection of another person's mental or emotional state. Therefore, decoding these emotions could be based on the interpretation of the interaction between emotional expressions of two characters.

The aim of the present study was to examine the role of the VM in social competitive emotions that involve perception of a dyadic emotional interaction. Additionally, since right versus left lesions are differentially involved in modulating emotion, the role of brain asymmetry was also examined.

To test the ability of patients with localized cortical damage to understand gloating, envy and identification, we manipulated a simple mentalizing task (see also Shamay-Tsoory *et al*., 2007), based on Baron-Cohen's eye gaze task (1995). In this task, subjects were asked to judge when a character is envious of someone, gloating at their misfortune or identifying with them, based on the interaction between a character and the protagonist's facial expression. It was hypothesized that patients with VM damage will show a selective impairment in recognition of envy and gloating. Given the role of the PFC in ToM and perspective taking, it was reasoned that patients with VM damage will also show impaired basic ToM and perspective taking abilities. It was further hypothesize that basic ToM and perspective taking abilities will show positive correlation with the ability to recognize envy and gloating.

Materials and methods

Subjects

Patients with acquired localized, well-defined brain lesions of various aetiologies, referred to the Cognitive Neurology Unit for cognitive assessment, were recruited for participation in the present study. Aetiologies included head injury, meningioma and cerebrovascular accident (CVA) (Table 1). Testing was conducted at the chronic phase of recovery (at least 6 months post-trauma or-surgery). Special effort was made to diagnose diffuse axonal injury (DAI) following head trauma. Patients with signs of DAI in the MRI were excluded.

A neurologist who was blind to the study's hypotheses and the neuropsychological data carried out anatomical classification based on acute and recent CTs or MRIs. For patients with head injury, both the acute neuroradiological studies (performed within the first 24–48 h postinjury) and the chronic-recent scans were examined. For inclusion, lesions had to be localized to prefrontal or non-prefrontal regions. Prefrontal and posterior lesions included cases with gray and white matter damage. Localization of lesions was determined using standard atlases (Damasio, 2006) and was further transcribed from CT and MRI images to the appropriate slices of the MRIcro program (Rorden, University of Nottingham, UK). The MRIcro program allows drawing three-dimensional regions of interest (ROIs) on the basis of MRI and CT data, and enables the computation of volumes of regions of the brain that have sustained damage. A neurological examination was conducted prior to the cognitive assessment and patients suffering from visual impairment, language deficits or motor limitations that might interfere with the performance of the neuropsychological tasks were excluded.

Patients were divided into prefrontal (PFC, $n = 32$) and posterior ($n = 16$) subgroups, on the basis of the location of the lesion. The PFC subgroup (27 males, five females) consisted of 26 patients with a unilateral lesion (left hemisphere = 9, right hemisphere = 17) and six patients with bilateral lesions. The posterior subgroup (10 males, six females) included 16 patients with unilateral lesions (left hemisphere = 10, right hemisphere = 6).

The PFC group was further divided into subgroups according to the prefrontal sectors of functional significance (Damasio and Damasio, 1989; Damasio, 2005): dorsolateral [DLC, including the superior frontal gyrus (SFG) and dorsal parts of the middle frontal gyrus (MFG), Brodmann areas dorsolateral 8, 9 and 44, 45, 46]; VM [including the frontal pole (FP), inferior fontal gyrus (IFG), middle orbital gyrus (mOrbG), and ventral parts of the MFG, Brodmann areas 6, mesial 8, 9, 10, 24, 32 and orbital Brodmann areas 10, 11, 12, 14] and MIX (DLC + VM). Nineteen patients had lesions confined to a single sector (DLC = 9, VM = 10), and 13 had a MIX lesion.

The posterior group was also divided into subgroups according to the posterior sectors of functional significance: Superior Parietal Lobule [SUP, including the superior parietal lobule (SPL),

Table 1 Details of patient lesions

Subject	Localization	Aetiology
Ventromedial (VM)		
1	Left frontal	Meningioma.
2	Bilateral frontal	Head injury: contusion, haematoma
3	Bilateral frontal	Head injury: contusion
4	Right frontal	Head injury: haematoma, encephalomalacia
5	Left frontal	Head injury: haematoma
6	Left frontal	Head injury: haematoma, encephalomalacia
7	Right frontal	Head injury: encephalomalacia
8	Right frontal	Head injury: encephalomalacia
9	Left frontal	Head injury: haematoma, contusion, lobotomy
10	Bilateral frontal	Meningioma
Dorsolateral (DLC)		
11	Right frontal	Aca aneurism, craniotomy
12	Left fronto-temporal	Head injury: contusion, haematoma
13	Right frontal	Head injury: contusion
14	Right frontal	CVA–MCA
15	Right frontal	Pentrating object
16	Left frontal	Meningioma
17	Right frontal	Meningioma
18	Right frontal	CVA: haematoma
19	Right frontal	Head injury: haematoma
Ventromedial and dorsolateral (MIX)		
20	Right frontal	Head injury: contusion, haematoma
21	Right frontal	Head injury: haematoma, contusion
22	Right frontal	Head injury: contusion, haematoma
23	Right frontal	Glioblastoma
24	Left frontal	Head injury: contusion, haematoma
25	Right frontal	Head injury: haematoma, contusion
26	Bilateral fronto-temporal	Head injury: contusion
27	Left frontal	Head-injury: haematoma, encephalomalacia
28	Right fronto-temporal	Meningioma
29	Left frontal	Head-injury: haematoma, encephalomalacia
30	Bilateral frontal	Pentrating head injury: haematoma
31	Right frontal	Head-injury: contusion, haematoma
32	Right frontal	Anaplastic astrocytoma
Superior Parietal (SUP)		
33	Right parietal	Penetrating head injury: contusion, haematoma
34	Right parietal	CVA: haematoma
35	Right parietal	CVA, infarct
36	Left parietal	Head injury: encephalomalacia
37	Left parietal	Head injury: contusion, haematoma
Inferior Parietal (INF)		
38	Left parietal	Head-injury: encephalomalacia
39	Left temporo-parietal	Head injury: haematoma
40	Left parietal	Pilocytic astrocytoma
41	Left parietal	Oligodendroglioma
42	Left temporo-parietal	CVA: haematoma
43	Left temporo-parietal	Melanoma, craniotomy
Mesial Temporal (Temp)		
44	Left temporal	Head injury: haematoma
45	Right temporal	Meningioma
46	Right temporal	CVA, infarct
47	Right temporal	Head injury: contusion, haematoma
48	Left temporal	Head injury: haematoma

post-central gyrus (post-CG) and pre-central gyrus (pre-CG), Brodmann areas 7, 5]; Inferior Parietal Lobule and Superior temporal gyrus [INF, including the inferior parietal lobule (IPL), angular gyrus (AG), supramarginal gyrus (SMG), superior temporal gyrus (STG), Brodmann areas 40, 39, 22, 37] and Mesial Temporal [Temp, including the temporal pole (TP), middle temporal gyrus (MTG) and inferior temporal gyrus (ITG), Brodmann areas 20, 21, 22, 20, 28, 38]. Classification of PC patients was to the following subgroups: SUP = 5; INF = 6; Temp = 5. In the INF subgroup, one patient also had a small occipital lesion in Brodmann area 19.

The volume of lesions ranged from 0.9 cm^3 to 138.32 cm^3 (mean = 30.213 cm^3, SD = 28.254 cm^3) and did not differ among the different lesion groups ($F[6,42] = 0.650$, NS). The overlap maps of lesions for the six groups of brain-damaged subjects are shown in Fig. 1.

In one patient with VM damage, in two patients with MIX damage and in two patients with DLC damage, the lesions also extended to the temporal lobes. In one patient with DLC damage, the damage also included a small left parietal lesion.

Thirty-five age-matched healthy volunteers (HC) served as controls. The HC group included 19 women and 18 men, aged 18 to 61 years, with 12–16 years of education. All participants were fluent in Hebrew and none had a history of developmental or psychiatric conditions. Subjects with a history of alcohol or drug abuse or previous head trauma with loss of consciousness were excluded. All participants signed an informed consent form. Ethical approval was granted by the hospital's Ethics Committee. Testing was conducted in two sessions; three patients did not show up for the second sessions and 10 subjects did not complete at least one of the tasks. The seven groups (six patient groups and HC) did not differ in years of education ($F[6,76] = 1.079$, NS); however, they did differ in age ($F[6,76] = 2.881$, $P = 0.014$). *Post hoc* analysis (Bonferroni) indicated that the SUP group were older and differed significantly from the HC group ($P = 0.047$). The rest of the groups did not differ from each other.

Assessment of first order cognitive and affective ToM

This computerized task (programmed using E-prime) is based on a task described previously by Baron-Cohen *et al.* (1995) and involves the ability to judge mental states based on verbal and eye gaze cues (a variation of this task was used in Shamay-Tsoory *et al.*, 2007). The task consists of 36 trials presented randomly, each showing a cartoon outline of a face (named Yoni) and four coloured pictures of objects belonging to a single category (e.g. fruits, chairs) or faces, one in each corner of the computer screen. The subject's task was to point to the correct answer (the image Yoni is referring to), based on a sentence that appears at the top of the screen, and available cues such as Yoni's eye gaze and Yoni's facial expression (Fig. 2). The subjects are instructed to point at the correct picture using the computer mouse as fast as they can. There were two first-order mentalizing conditions that appeared in random order: 'cognitive' (12 trials) and 'affective' (12 trials). While in the *cognitive* condition Yoni's facial expression is neutral, in the *affective* conditions Yoni's facial expression is affective [Yoni is thinking of ___ (cognitive condition) versus Yoni loves___ (affective condition)].

In addition, 12 trials involved physical inference ('Yoni is near____'). The cognitive and the affective conditions involved

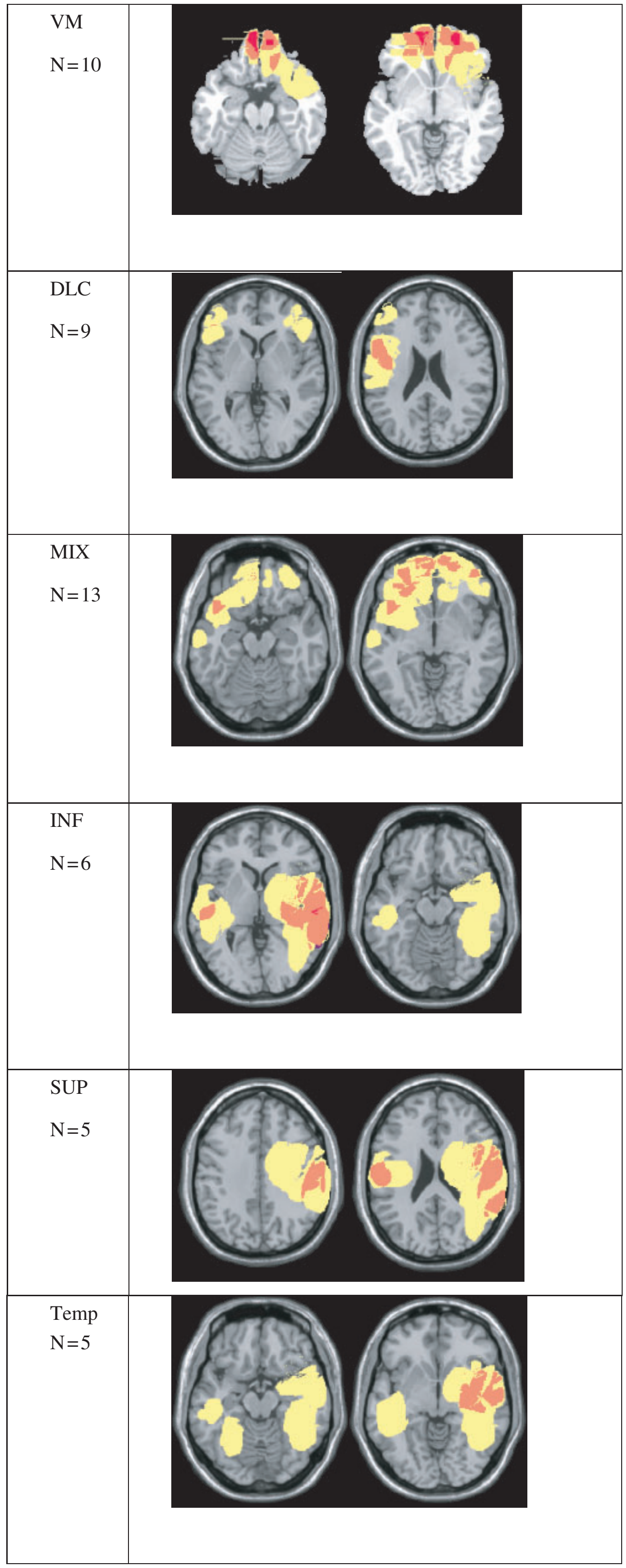

Fig. 1 Overlap maps of lesions.

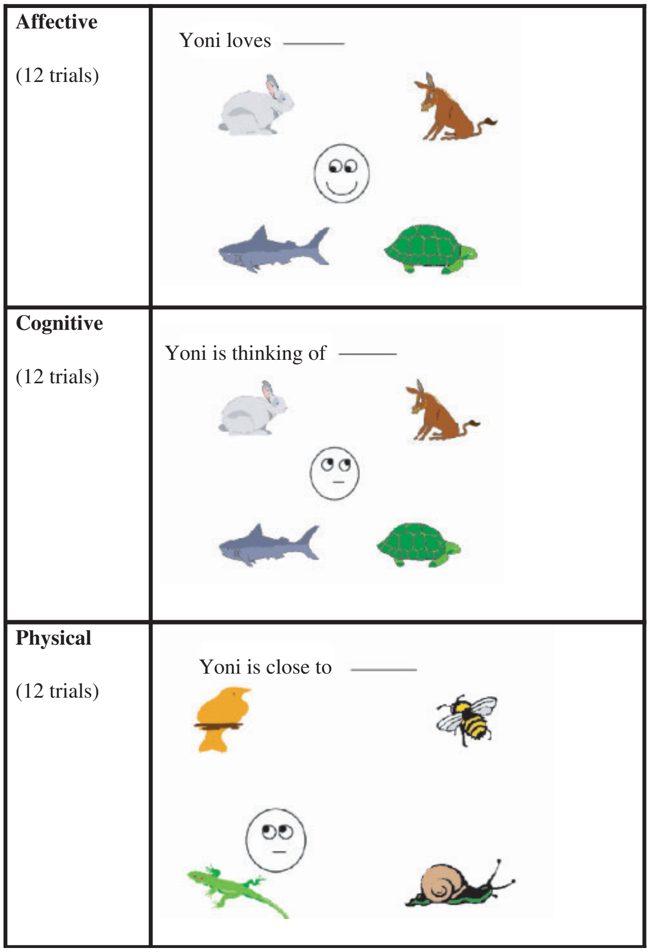

Fig. 2 Sample of items: cognitive and affective mental inference and a mentalistic significance of eye direction.

mental inferences while the physical conditions required a choice based on a physical attribute of the character (thus serving as a control condition, to ensure that the subject understands the task).

Recognition of 'fortune of others' emotions: gloating, envy and identification

To assess recognition of envy, gloating and identification, we modified the afore mentioned task by adding 'fortune of others' conditions. As in the ToM task, Yoni appeared at the center of the screen. However, the four stimuli at the corners of the screen consisted only of face images (rather than objects) displaying neutral, positive or negative facial expressions, and the choice of the correct response required understanding of the interaction between the characters' emotional state and Yoni's affective mental state.

Pre-test

In this preliminary study, 27 healthy individuals rated a set of 30 stimuli which consisted of Yoni and several protagonists with neutral positive and negative facial expressions. The pictures depicting positive and negative and neutral affects of the characters were selected from Ekman and Friesen (1976) and from available cartoons. The raters were asked to select the emotion that best described the emotional interaction between Yoni and the other character, choosing from a list of 10 negative and positive social emotions (envy, apologetic, embarrassment, identification, shame, gloating, pride, guilt, arrogance and regret). To ensure that the subjects understood all the terms, they were first asked to describe a situation in which each emotion may appear. Two subjects failed to provide the correct definitions of one emotion (one with identification and the other arrogance). These subjects were then provided with the correct definition of the emotion and asked again to describe a situation in which the emotion may appear. Both of them showed a good understanding of the emotion term after this procedure.

The subjects in the pre-test were asked to choose from the list social emotions how Yoni feels towards the protagonist he is gazing at.

Analysis of the raters' results indicated that 81% of the sample chose the indented emotion (for example, when Yoni's facial expression was sad and the protagonist's facial expression was happy, the raters chose the word envy to describe the interaction between them). To ensure validity, a subset of stimuli was selected, based on a high degree (>85%) of agreement among raters.

Task

Among the items that were selected based on the pre-test, the four stimuli at the corners of the screen consisted only of face images displaying neutral, positive or negative facial expressions (happy, sad, angry, fearful, surprised and neutral).

In the envy condition, Yoni's facial expression was negative (frowning) while the protagonist's facial expression was always positive (happy). Therefore, the correct response was happy while the distractors were a combination of sad, neutral, fearful or angry. In the gloating condition, Yoni's facial expression was positive (smiling) while the protagonist's facial expression was negative (sad). Therefore, the correct response was sad while the distractors were a combination of happy, neutral or surprised. In the identification condition, Yoni's expression matched the protagonists' expression (sad and sad, happy and happy). The surprised, neutral and angry expressions were added since it was reasoned that if we use only sad and happy faces the task would be too easy. While the surprised, fearful, neutral and angry expressions always served as distractors, the sad and happy were sometimes targets and sometimes the distractors. As may be seen in Fig. 3, in the envy condition Yoni's facial expression was negative while the protagonist's facial expression was positive. In the gloating condition, Yoni's facial expression was positive while the protagonist's facial expression was negative. In the identification condition, Yoni's expression matched the protagonists' expression.

As in the basic ToM task, the subjects were instructed to point at the correct picture using the computer mouse as fast as they could. There were three 'fortune of others' conditions: 'envy' (eight trials), 'gloating' (eight trials) and 'identification' (eight trials). As shown in Fig. 3, a physical condition in which subjects were required to match the similarity between Yoni and the protagonist's facial expression was intended to test basic understanding of the task demands.

Another condition in which Yoni's gaze was straight ahead was added to prevent subjects from automatically responding to the

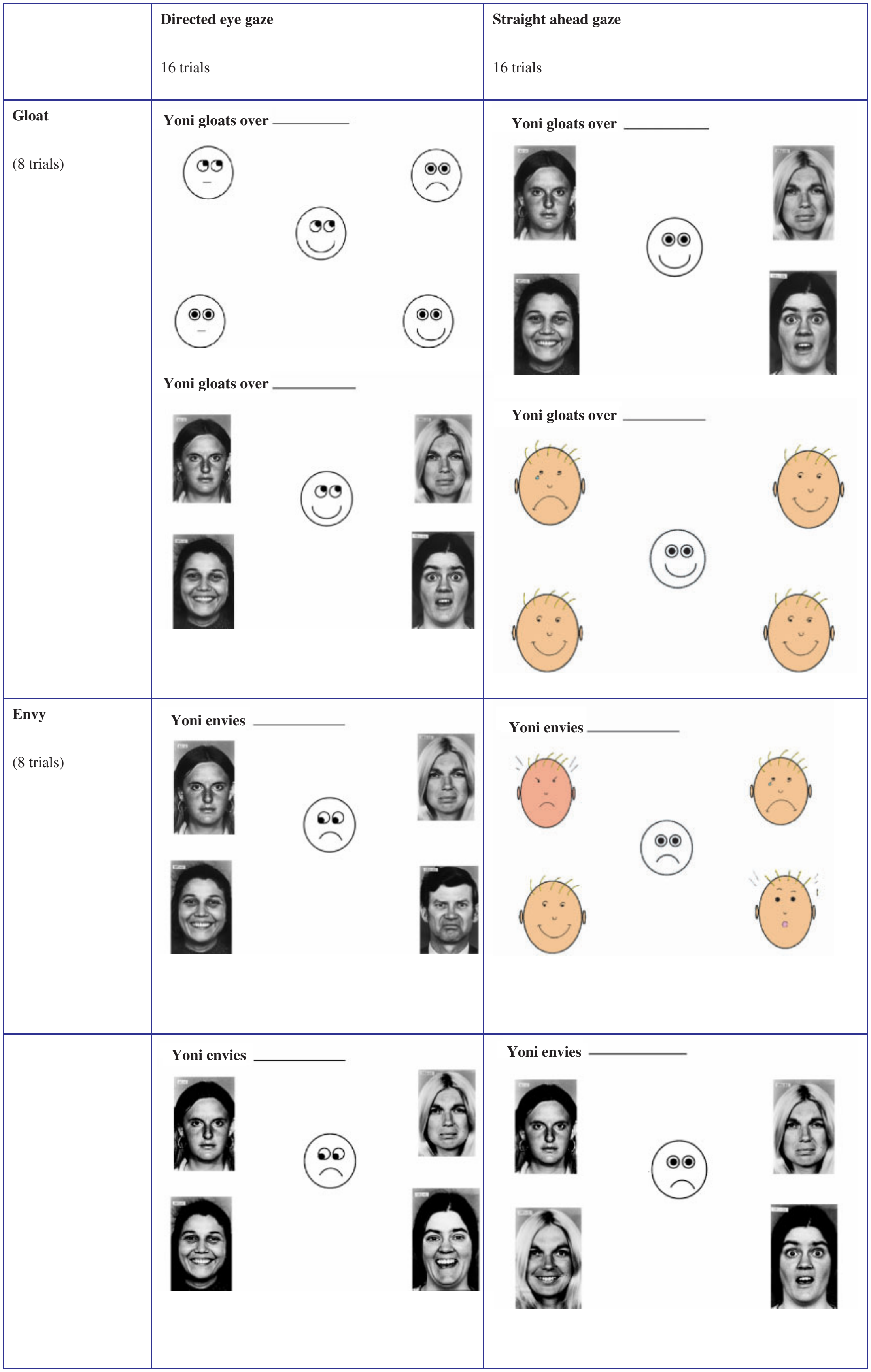

Fig. 3 Sample of items: recognition of 'fortune of others' emotions: gloating, envy and identification.

Fig. 3 Continued.

stimulus at which Yoni's gaze was directed without reading the instruction sentence. When Yoni's gaze was directed straight ahead, the decision was based on the verbal cue (the instruction sentence) and the facial expressions of Yoni and the other characters. Thus, in half the trials, Yoni's eye gaze was directed at one of the four face stimuli (thus indicating the correct answer) and in the other trials Yoni's gaze was directed straight ahead and the correct response could not be based on eye gaze. The subject's performance was rated for accuracy in each trial.

Recognition of basic emotional expression

This task was designed to assess the individual's ability to recognize basic emotions. Experimental studies have argued that emotional states are recognized disproportionately by information from the region of the eyes (Adolphs *et al*., 2002; Baron-Cohen *et al*., 2001). Therefore, the test consisted of 24 photographs of eyes expressing six 'basic emotions' [taken from Ekman and Friesen (1976): happy, sad, afraid, surprised, disgusted and angry]. Stimuli were produced using Ekman's original picture as source material. At the bottom of each picture stimulus, two words are printed, one describing the correct emotion expressed and the other a distractor from the correct response.

Neuropsychological assessment

All patients completed the Raven's Progressive Matrices to assess reasoning, to obtain an estimate of general intellectual functioning (Beaumont and Davidoff, 1992). Executive functions were assessed by The Wisconsin Card Sorting Test (WCST), administration and scoring followed Heaton *et al*. (1993) and Verbal Fluency [category (animals, fruits and vegetables) and letter fluency]. The Digit Span and Similarities subscales from the WAIS-R were used to assess attention span and verbal reasoning, respectively.

Assessment of perspective taking abilities

Perspective-taking abilities were assessed using the perspective-taking subscale taken from the Interpersonal Reactive Index (IRI) (Davis, 1983). The perspective-taking subscale measures the reported tendency to adopt spontaneously the psychological point of view of others (i.e. 'I sometimes try to understand my friends better by imagining how things look from their perspective.'). This scale was chosen based on previous findings regarding its high validity and its relation to measurements of ToM (Shamay-Tsoory *et al*., 2005).

Results

Neuropsychological assessment

All patients performed within the normative range with respect to the WAIS, Raven and WCST. The SUP group scored at the lower range of normative performance values in the verbal fluency tasks. As Table 2 indicates, the patient groups did not differ from each other in measurements of attention and executive functions. The groups differed only on the WAIS-R Similarities sub-scale ($F[5,33] = 3.486$, $P = 0.012$). *Post hoc* analysis (Bonferroni) indicated that the MIX group had significantly lower scores than the SUP group ($P = 0.028$). The other subgroups did not differ from each other.

Table 2 Patient performance on measurements of executive functions, attention, RAVEN and similarities

	VM PFC	DLC PFC	MIX PFC	INF PC	SUP PC	Temp
WCST						
Perseverative errors	11.33	14.33	11.15	7.5	11.75	16.60
Mean (SD)	(7.96)	(4.89)	(8.02)	(4.12)	(5.62)	(7.89)
Digit Span						
Age-scaled score	9.75	7.00	7.07	8.75	8	7.8
Mean (SD)	(3.37)	(1.2)	(2.13)	(2.63)	(1.41)	(2.42)
Fluency Phonemic						
Number of responses	13.8	13.8	9.46	12.8	9.8	12.60
Mean (SD)	(6.46)	(6.45)	(4.76)	(4.32)	(4.32)	(5.13)
Fluency Semantic						
Number of responses	18.00	23.50	17.30	22.6	17.1	20.4
Mean (SD)	(6.30)	(7.76)	(6.00)	(8.01)	(3.63)	(7.44)
Similarities						
A ge scale	9.5	11.16	9.75	9.75	12.33	10.60
Mean (SD)	(1.13)	(1.94)	(1.50)*	(1.5)	(2.30)	(1.34)
Raven						
Percentile	50.8	40.40.	50.14	60.4	70	43.00
Mean (SD)	(27.89)	(25.06)	(35.43)	(27.67)	(35.36)	(30.97)

*Significantly different from the SUP.

Table 3 Percentage of correct responses in the cognitive and affective ToM and the understanding of 'fortune of others' emotions tasks

	VM	DLC	MIX	INF	SUP	Temp	HC
First order mentalization based on eye gaze							
Cognitive ToM	94.20	99.11	83.38*	91.69	98.4	100	97.17
Mean (SD)	(8.85)	(2.66)	(2.4)	(10.59)	(3.57)	(0)	(6.67)
Affective ToM	91.00	96.33	81.54*a	98.67	98.4	100	96.20
Mean (SD)	(17.67)	(8.4)	(27.26)	(3.26)	(3.57)	(0)	(6.85)
Physical inference	93.90	97.33	90.62	91.83	97.6	95.2	95.77
Mean (SD)	(8.72)	(5.29)	(9.98)	(10.12)	(5.36)	(6.57)	(9.47)
Understanding of 'fortune of others' emotions: envy, gloating and identification							
Envy	73.20*	88.89	76.85*	83.17	93.4	86.60	95.66
Mean (SD)	(26.35)	(18.89)	(25.01)	(18.25)	(14.76)	(13.87)	(8.50)
Gloat	74.90*	83.11	79.46*	69.33*	93.2	86.8	92.26
Mean (SD)	(21.14)	(15.49)	(17.74)	(24.54)	(9.31)	(18.07)	(9.45)
Identification	78.40	88.89	78.15.31	94.33	89.8	86.4	91.80
Mean (SD)	(25.96)	(14.34)	(21.94)	(87.78)	(9.31)	(7.60)	(10.26)
Physical inference	78.60	85.67	84.62	85.83	94.40	71.40	89.86
Mean (SD)	(28.09)	(20.24)	(18.91)	(15.70)	(7.66)	(26.73)	(16.80)

*Significantly better from the HC group.

First order mentalization based on eye gaze

The accuracy data for the two tasks are shown in Table 3. Separate ANOVA was conducted for each condition. Since multiple ANOVA comparisons were made, Bonferroni's correction was carried out and the criterion for significance was accepted as $P = 0.016$. No significant differences were observed between the groups in the physical condition ($F[6,76] = 0.925$, NS). Significant difference between groups were observed in the cognitive ToM ($F[6,76] = 2.99$, $P = 0.011$) and marginally in the affective ToM ($F[6,76] = 2.47$, $P = 0.031$) conditions. *Post hoc* analysis (Benferroni) indicated that the MIX group was significantly different from the HC group in both cognitive ToM ($P = 0.008$) and affective ToM ($P = 0.028$). The rest of the groups did not differ from each other.

Separate ANOVAs were also conducted for the reaction time (RT) scores in each condition. Significant differences were observed between the groups in the physical condition ($F[6,76] = 3.559$, $P = 0.004$), in the cognitive ToM ($F[6,76] = 4.05$, $P = 0.001$) and in the affective ToM ($F[6,76] = 3.761$, $P = 0.003$) conditions. *Post hoc* analysis (Benferroni) indicated that the MIX group was significantly slower than the HC in the physical ($P = 0.010$), the cognitive ($P = 0.0001$) and the affective ToM ($P = 0.0001$) conditions. This indicates that the MIX patients showed an overall tendency to react more slowly.

Understanding of 'fortune of others' emotions: envy, gloating and identification

Since multiple ANOVA comparisons were made, Bonferroni's correction was carried out and the criterion for significance was accepted as $P = 0.016$.

As shown in Table 3, one-way ANOVAs indicated significant differences between groups in the envy ($F[6,76] = 3.491$, $P = 0.004$) and gloat ($F[6,76] = 3.738$, $P = 0.003$), but not in the identification ($F[6,76] = 1.89$, NS) and physical (phy2) (F[6,76] = 1.113, NS) conditions. *Post hoc* analysis (Bonferroni) indicated that in the envy condition the VM ($P = 0.01$) and the MIX ($P = 0.01$) groups differed significantly from the HC, while in the gloat condition the VM ($P = 0.041$) and the INF ($P = 0.02$) groups differed significantly from the HC. The rest of the groups did not differ from each other.

Since few patients had errors in the physical condition (phy2), a multivariate ANOVA was conducted, with the physical condition (Phy2) serving as a covariate, to examine whether the patient groups and the controls differed significantly from each other on the envy, gloat and identification trials. This analysis indicated that accuracy in the physical condition did not have a significant effect on subjects' performance (Hotteling's Trace: $F[3,73] = 2.581$, NS) and the difference between the groups was still significant (Hotteling's Trace: $F[18,215] = 1.809$, $P = 0.026$). Furthermore, tests of between-subjects effects indicated that the groups differed significantly from each other in the envy ($F[6,75] = 2.47$, $P = 0.012$) and gloating ($F[6,75] = 3.69$, $P = 0.005$) conditions, but not in the identification condition

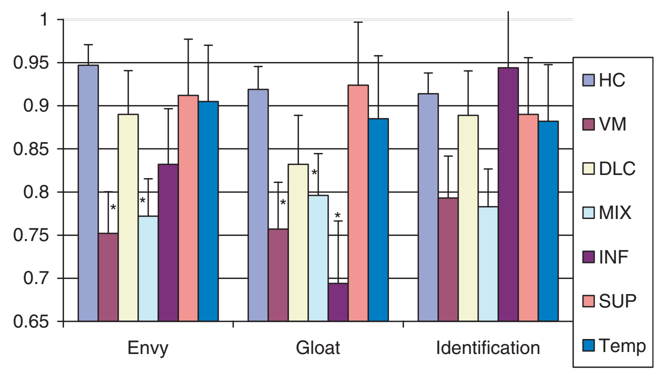

Fig. 4 Multivariate ANOVA indicated that the difference between the groups was significant (Hotteling's Trace: $F[18,215] = 1.809$, $P = 0.026$). Tests of between-subjects effects indicated that the groups differed significantly from each other in the envy ($F[6,75] = 2.47$, $P = 0.012$) and gloating ($F[6,75] = 3.69$, $P = 0.005$) conditions, but not in the identification condition ($F[6,75] = 1.644$, NS). Pairwise comparisons indicated specifically that in the envy condition the VM group was more impaired as compared with the HC ($P = 0.002$) and marginally from the DLC ($P = 0.07$) and SUP ($P = 0.08$) groups. The MIX group was also significantly impaired as compared with the HC group ($P = 0.002$). The rest of the groups did not differ from each other. In addition, in the gloating conditions, the VM group was more impaired as compared with the HC ($P = 0.005$) and SUP ($P = 0.05$) groups. The INF group was also significantly more impaired as compared with the HC ($P = 0.001$), the TEMP ($P = 0.041$) and SUP ($P = 0.014$) groups. The MIX group was also significantly impaired as compared with the HC group ($P = 0.015$).

($F[6,75] = 1.644$, NS). As shown in Fig. 4, pairwise comparisons indicated specifically that in the envy condition the VM group was more impaired as compared with the HC ($P = 0.002$) and marginally from the DLC ($P = 0.07$)and SUP ($P = 0.08$) groups. The MIX group was also significantly impaired as compared with the HC group ($P = 0.002$). The rest of the groups did not differ from each other. In addition, in the gloating conditions, the VM group was more impaired as compared with the HC ($P = 0.005$) and SUP ($P = 0.05$) groups. The INF group was also significantly more impaired as compared with the HC ($P = 0.001$), the TEMP ($P = 0.041$), and SUP ($P = 0.014$) groups. The MIX group was also significantly impaired as compared with the HC group ($P = 0.015$).

To examine differences among groups in RT scores to the fortune of other emotions, we conducted separate ANOVAs. Results indicated significant differences between groups in the envy ($F[6,76] = 3.872$, $P = 0.002$), gloating ($F[6,76] = 3.225$, $P = 0.007$), identification ($F[6,76] = 3.889$, $P = 0.002$) and in the physical ($F[6,76] = 3.006$, $P = 0.011$) conditions. *Post hoc* analysis (Benferroni) indicated that the MIX group was significantly slower than the HC in the envy ($P = 0.001$), in the gloating ($P = 0.003$), in the identification ($P = 0.001$) and in the physical ($P = 0.02$) conditions. This indicates that the MIX patients showed and overall tendency to react more slowly.

Gaze versus straight ahead conditions

As presented earlier, the 'fortune of others' task involved four different types of conditions: envy, gloating, identification and physical. Therefore, the primary variables of interest were the *type* of judgement (envy, gloating, identification and physical) and the gaze condition (gaze versus straight ahead). In order to obtain measures of the trends and interactions over the different types and gaze conditions, a three-way repeated measures ANOVA was conducted, with the type and gaze as the within-subjects factors and group as the between-subjects factor. This analysis revealed a significant group effect ($F[6,76] = 4.729$, $P = 0.0001$), indicating significant differences between groups in these variables. Pairwise comparisons indicated that the VM ($P = 0.001$) and the MIX ($P = 0.010$) group were significantly worse on these measures as compared with the HC groups. The rest of the groups did not differ from each other. A significant type effect ($F[3,74] = 2.805$, $P = 0.046$) indicated a significant difference in accuracy between types (envy, gloating, identification and physical). Pairwise comparisons indicated that the accuracy scores in the physical conditions were significantly higher than in the gloating ($P = 0.027$). The rest of the conditions did not differ from each other. The gaze effect ($F[1,76] = 8.865$, $P = 0.004$) was also significant and pairwise comparisons indicated that participants were more accurate in the gaze as compared with the straight ahead conditions ($P = 0.004$).

A non-significant group by gaze (two-way interaction) effect ($F[6,76] = 1.623$, NS) and a non-significant gaze by type by group (three-way interaction) effect ($F[18,218] = 0.742$, NS) indicated that the pattern of accuracy in the gaze and straight ahead conditions did not differ between groups. Follow up separate one way-ANOVA revealed significant differences between groups in the envy straight ahead ($F[6,76] = 2.279$, $P = 0.045$) and gaze ($F[6,76] = 3.041$, $P = 0.01$) conditions. *Post hoc* analysis (Benferroni) indicated that the VM group was significantly impaired in the envy straight ahead condition as compared with the HC ($P = 0.05$). No group differences were observed in the gaze conditions. Separate one-way ANOVA revealed significant differences between groups in the gloating straight ahead ($F[6,76] = 2.702$, $P = 0.02$) but not in the gaze ($F[6,76] = 1.351$, NS) condition. *Post hoc* analysis (Benferroni) indicated that the MIX group was significantly impaired in the gloating straight ahead condition as compared to the HC ($P = 0.002$). The rest of the groups did not differ from each other.

Lesion asymmetry

In order to examine whether the asymmetry of the lesion was an important factor contributing to the deficit in 'fortune of others' emotion, we re-divided the patients into new subgroups depending on the side of the lesion (right [RT], left [LT] and bilateral lesions).

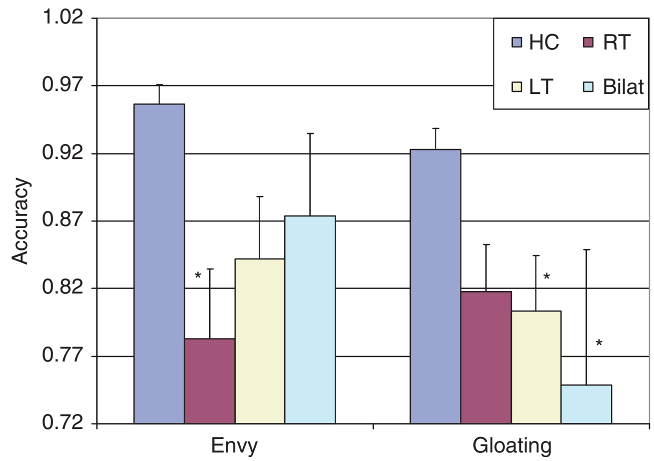

Fig. 5 One-way ANOVA revealed significant differences between groups in recognizing envy ($F[3,79] = 4.911$, $P = 0.004$) and gloating ($F[3,79] = 4.480$, $P = 0.006$) but not in recognizing identification ($F[3,79] = 1.897$, NS). *Post-hoc* analysis (Bonferroni) indicated that while in the envy condition the patients with the right sided lesions (RT) were significantly impaired as compared with the HC ($P = 0.002$), in the gloating condition the LT ($P = 0.05$) and the bilateral ($P = 0.034$) patients were significantly impaired as compared with the HC. The rest of the groups did not differ from each other.

A multivariate ANOVA of (lesion location × hemisphere) was conducted, to examine whether the asymmetry of the lesion was an important factor in the recognition of envy, gloating and identification, and whether there was an interaction between the location of the lesion (VM,DLC,MIX,INF,SUP,Temp,HC) and side of the lesion (RT versus LT). The multivariate ANOVA showed a significant lesion location effect ($F[5,68] = 2.013$, $P = 0.014$), significant lesion side-effect ($F[2,68] = 2.496$, $P = 0.026$) and a significant lesion location by side-effect ($F[6,68] = 2.002$, $P = 0.011$). Follow-up one-way ANOVAs revealed significant differences between sides in recognizing envy ($F[3,79] = 4.911$, $P = 0.004$) and gloating ($F[3,79] = 4.480$, $P = 0.006$) but not in recognizing identification ($F[3,79] = 1.897$, NS). As shown in Fig. 5, *post hoc* analysis (Bonferroni) indicated that while in the envy condition the patients with the right sided lesions (RT) were significantly impaired as compared to the HC ($P = 0.002$), in the gloating condition the LT ($P = 0.05$) and the bilateral ($P = 0.034$) patients were significantly impaired as compared with the HC. The rest of the groups did not differ from each other.

The neuroanatomy of envy and gloating

In order to identify the most critical lesion associated with the most severe deficit in envy and gloating the patients were further assigned into two groups ('impaired' and 'non-impaired' groups) according to their scores in these particular conditions (<50% of accuracy).

Envy

The 'impaired' group consisted of eight patients (three had a VM lesion, three MIX, one INF, one DLC) with mean score of 0.415 of accuracy (SD = 0.0098) and 40 'non-impaired' patients with mean score of 0.901 (SD = 0.122). Once the patients had been dichotomized into 'impaired' versus 'non-impaired' groups, a chi-square analysis of their frequencies in each neuroanatomical category (VM, DLC, MIX, INF, SUP, HC) was conducted. Significant differences were observed ($\chi^2 = 14.665$, df = 6, $P = 0.023$) indicating that the distribution of individuals between the 'impaired' an 'non-impaired' groups was significantly different than expected.

To examine asymmetry of lesions a chi-square analysis of their frequencies in each lesion side category (RT, LT, bilateral and control) was conducted. In the impaired group 5 had RT lesions, 2 LT and 1 bilateral. Significant differences were observed ($\chi^2 = 7.764$, df = 4, $P = 0.05$) indicating that the distribution of individuals between the 'impaired' an 'un-impaired' groups was significantly different than expected.

Gloating

The same analysis was carried out in the gloating condition. The 'impaired' group consisted of six patients (one with a VM lesion, one in the DLC, two MIX and two INF) with mean score of 0.44.33 of accuracy (SD = 0.087) and 42 'non-impaired' patients with mean score of 0.8602 (SD = 0.1308). It is important to note that three patients from the gloating-impaired group were also included in the envy-impaired group. Chi-square analysis of the 'impaired' versus 'non-impaired' frequencies in each neuroanatomical category (VM, DLC, MIX, INF, SUP, HC) yielded a marginally significant effect ($\chi^2 = 11.499$, df = 6, $P = 0.074$).

To examine asymmetry of lesions a chi-square analysis of their frequencies in each lesion, side category (RT, LT, bilateral and control) was conducted. In the impaired group, three had RT lesions, two LT and one bilateral. Marginally significant differences were observed ($\chi^2 = 7.70$, df = 4, $P = 0.053$) indicating that the distribution of individuals between the 'impaired' an 'non-impaired' groups was marginally significantly different than expected.

As shown in Fig. 6, superimposition of the lesions of the envy-impaired and the gloating-impaired groups demonstrates that while envy is particularly affected by right VM lesions gloating is affected by both right VM and left INF lesions.

To rule out the possibility that impaired recognition of basic emotions might have an effect on identifying social emotions, we reanalysed the results with the performance on the recognition of basic emotion as a covariate. This analysis revealed no significant effect for the basic emotion recognition and the difference between groups in the social emotion task remained significant ($F[18,167] = 1.991$, $P = 0.013$).

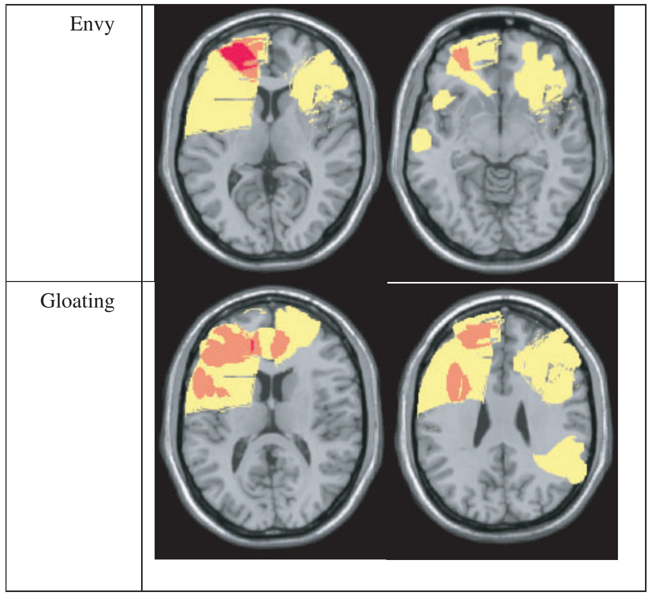

Fig. 6 superimposition of the lesions of the envy-impaired and the gloating-impaired groups demonstrate that while envy is particularly affected by right VM lesions gloating is affected by both right VM and left INF lesions.

Additionally, since age differed significantly among the groups it was used as a covariate. The multivariate ANOVA results suggested that the significance remained even with the age ($F[6,75] = 1.784$, $P = 0.029$) as a covariate.

To rule out the possibility that impaired recognition of 'fortune of others' emotions could be related to demographic variables, such as intellectual functioning (as measured by RAVEN matrices and Similarities), executive functions and years of education, a correlation analysis was conducted between these variables. Since multiple correlations were made, Bonferroni's correction was carried out and the criterion for significance was accepted as $P = 0.005$. Correlation analysis revealed no significant correlation between envy and Raven's test ($r = 0.378$, NS), similarities ($r = 0.176$, NS), WCST number of set losses ($r = -0.169$, NS), WCST number of perseverative errors ($r = -0.176$, NS), WCST number errors ($r = -0.262$, NS), digit span ($r = -0.038$, NS), phonemic fluency ($r = 0.422$, NS), semantic fluency ($r = 0.409$, NS), and age ($r = -0.258$, NS). Similarly, gloating did not correlate with Raven's test ($r = 0.290$, NS), similarities ($r = 0.087$, NS), WCST number of set losses ($r = -0.294$, NS), WCST number of perseverative errors ($r = -0.043$, NS), WCST number errors ($r = -0.125$, NS), digit span ($r = -0.058$, NS), phonemic fluency ($r = 0.261$, NS), semantic fluency ($r = 0.252$, NS) and age ($r = -0.171$, NS).

Finally, to rule out the possibility that gender differences have affected the results an independent *t*-test was conducted with the gender as the between subject variable and gloating and envy accuracy scores as the dependent variable. Results indicated the males and females did not differ on their performance in the envy

[$t(81) = -0.005$, NS] as well as in the gloating [$t(81) = -0.140$, NS] conditions.

Relation between perspective-taking, first order ToM, basic emotion and 'fortune of others' emotions

A one-way ANOVA was conducted to analyse differences in recognition on different basic emotions. This analysis did not indicate a significant group effect on the total score of emotions ($F[6,60] = 2.004$, NS). Non-significant differences between groups were observed in the happy ($F[6,60] = 1.544$, NS), sad ($F[6,60] = 1.951$, NS), fear ($F[6,60] = 1.093$, NS), anger ($F[6,60] = 1.386$, NS) and disgust ($F[6,60] = 2.376$, $P = 0.04$) conditions. However, significant differences were observed in recognizing and surprise ($F[6,60] = 3.00$, $P = 0.013$). *Post hoc* (Bonferroni) analysis indicated that, in recognition of surprise, the DLC was significantly worse than the HC ($P = 0.012$). The rest of the groups did not differ from each other.

A one-way ANOVA test was conducted to analyse differences between groups in perspective-taking scale scores. This analysis indicated significant differences between groups ($F[6,64] = 6.006$, $P = 0.0001$). *Post hoc* analysis indicated that patients with lesions in the VM had significantly lower scores than the SUP ($P = 0.0001$) and the HC ($P = 0.0001$) groups. No significant differences were found between the other groups.

Correlation analysis was conducted to test the relationship between perspective-taking, cognitive and affective ToM, recognition of basic emotions and perception of 'fortune of others' emotions. As shown in Table 4, the recognition of envy and gloating but not identification correlated with the perspective-taking subscale. In addition, perception of envy also correlated significantly with both affective and cognitive ToM. A significant correlation was observed between affective ToM condition and perception of identification. No significant correlation was observed between the ability to recognize 'fortune of others' emotions and the ability to recognize basic emotions.

Table 4 Correlation analysis: the relation between perspective-taking, first-order ToM, identification of basic emotions and 'fortune of others' emotions

	Cognitive ToM	Affective ToM	Perspective -taking	Recognition of basic emotions
Envy	*$r = 0.283$	**$r = 0.355$	*$r = 0.314$	$r = 0.118$
	$P = 0.01$	$P = 0.001$	$P = 0.008$	NS
Gloat	$r = 0.170$	$r = 0.056$	**$r = 0.339$	$r = 0.120$
	NS	NS	$P = 0.004$	NS
Identification	$r = 0.193$	*$r = 0.239$	$r = 0.143$	$r = 0.188$
	NS	$P = 0.029$	NS	NS

*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

Discussion

The mentalizing network and its role in recognizing envy and gloating

In the present study, we assessed basic ToM and emotion recognition capacities as well as the ability to understand 'fortune of others' emotions in patients with localized brain lesions. We speculated that the ability to understand particularly competitive emotions, such as gloating and envy, is related to a broader mentalizing and perspective taking capacities and that, therefore, lesions in the VM may impair the ability to understand these emotions. Our results support this hypothesis by showing selective impairment in recognizing gloating and envy but not identification in patients with VM damage. Contrary to our initial hypothesis, these patients did not show impaired performance on basic first order ToM tasks based on eye gaze. However, in accordance with our hypothesis, it was shown that VM patients did show impaired perspective taking abilities.

Furthermore, correlation analysis indicated that the perception of 'fortune of others' emotions was related not only to ToM but also to perspective-taking abilities. The ability to understand envy and gloating, but not identification, was particularly related to perspective taking scales.

These results are consistent with findings that children with autism reveal a less coherent understanding of jealousy (Bauminger, 2004), an emotion with characteristics similar to envy that may co-occur in equivalent situations (Parrot, 1991). Since ToM difficulties in autism are well established (Klin *et al.*, 2003), it is likely that emotions such as envy and gloat which involve social comparisons will be perceived differently in these individuals.

Indeed, the involvement of the VM in 'fortune of others' emotion is consistent with its role in ToM. As already mentioned, previous neuroimaging studies (Baron-Cohen *et al.*, 1994; Fletcher *et al.*, 1995; Goel *et al.*, 1995; Gallagher *et al.*, 2000; Calarge *et al.*, 2004; Grezes *et al.*, 2004) and lesion studies (Stone *et al.*, 1998; Stuss *et al.*, 2000; Rowe *et al.*, 2001) reported findings concerning the contribution of specific PFC regions to ToM abilities. In the present study, only patients with MIX (DLC and VM) damage showed impaired basic ToM abilities. The VM patients were not different from the HC in the basic ToM task although they had a poorer performance and they were impaired in the perspective taking task. The ToM task used in the present study represents a first order mentalizing inference. In accordance with these results, it has been shown that patients with damage that encompasses the VM do not usually show impaired first order ToM (Stone *et al.*, 1998). It has been further suggested that the VM is involved in complex, more affective, mentalizing conditions rather than in basic ToM (Stone *et al.*, 1998; Shamay-Tsoory *et al.*, 2005). Furthermore, a report by Mitchell *et al.* (2005) demonstrates that the VM may guide the understanding of others' complex mental states through affective 'simulation' processing. Additional support for the role of the VM may be found in the intimate connections of the VMPFC with the anterior insula, temporal pole, inferior parietal region and amygdala, which place this region in a position to integrate limbic input with complex frontal information that can consequently be used to understand complicated social emotions.

Gloating versus envy

While VM damage was associated with impaired recognition of both gloating and envy, recognition of gloating involved additionally lesions in the inferior parietal lobule. In line with this finding, recent experimental reports suggest that the temoporo-pariental junction and the superior temporal sulcus (STS) play a prominent role in attribution of beliefs (Apperly *et al.*, 2004; Samson *et al.*, 2004). The inferior parietal area was also found to be particularly important in tasks that involved emotional perceptual analysis (Herberlein *et al.*, 2004). Moreover, Chaminade and Decety (2002) suggested that a neural network that involves the inferior parietal cortex and the prefrontal cortex plays a special role in the essential ability to distinguish the self from others, and in the way the self represents the other. In a later study, Ruby and Decety (2004) examined the difference between adopting first- and second-person perspective in response to situations involving social emotions. The authors reported an increase in the haemodynamic response in the medial PFC, the STS and the right inferior parietal lobe in third-person versus first-person perspectives.

Gloating (schadenfreude), similarly to envy, is a social comparative emotion that involves both the perception of another's negative emotion and, in consequence, one's own positive emotion. In the present study, understanding of gloating involved perspective taking abilities. Therefore, it is not surprising that lesions in the mentalizing network that include the VM and the inferior parietal lobe were associated with impaired identification of gloating. One may speculate whether gloating which appears to be less basic or automatic than envy may involve more prominent participation of structures from the mentalizing network.

The inferior parietal lobe including the STS has been also associated with determination of the direction of the other person's gaze (Wicker *et al.*, 1998; Hoffman and Haxby, 2000). Additionally, Calder *et al.* (2002) have suggested that the medial PFC regions are also involved in gaze direction. Furthermore, the authors demonstrated a considerable degree of overlap between the medial frontal areas involved in eye gaze processing and theory of mind tasks (Calder *et al.*, 2002). The task used in the present study involved recognition of envy and gloating based on different cues, including eye gaze direction. Given the role of the medial PFC and the STS in detection of eye gaze, it would be expected that the VM and the INF groups will not show advantage in the gaze versus no-gaze conditions. However, our results indicated that the pattern of accuracy in gaze and in straight ahead conditions did not differ between groups. Overall, all participants performed better in the gaze direction conditions and even patients with inferior parietal damage and patients with medial prefrontal damage where doing better when the eyes were directed towards the protagonist. We believe that the directed eye-gaze conditions were easier to interpret since the stimuli included an additional cue that was not included in the straight ahead conditions (the eye-gaze clue). Since the difference between these two conditions does not interact with the group variable, it may support our assumption that the significant differences observed above are not due to the difference between the two conditions.

Another difference between gloating and envy was manifested in the asymmetry of lesions associated with impaired recognition of these emotions. While left-sided lesions were associated with impaired understanding of gloating, right sided lesions were more related to recognition of envy. Several attempts have been made to explain the contribution of hemispheric lateralization for emotional processing. While traditional views have hypothesized that the right hemisphere has a central role in modulating all forms emotional processing (Mandal *et al.*, 1996), the 'valence hypothesis' suggested dissociable roles for the right and left hemispheres in modulating emotions. According to this formulation, the left hemisphere is dominant for positive emotions (such as happiness) and the right hemisphere is dominant for negative emotions (such as sadness) (Davidson 1992).

While envy is usually a very unpleasant emotion (Parrot, 1991), a misfortune befalling an envied other can be even pleasing as it eliminates the basis of envy (inferiority) (van Dijk *et al.*, 2006). Gloating involves a conflict between our pleasure or positive evaluation of the situation and the other's misfortune or negative evaluation of the other person, raising the competitive aspect of this emotion (Ben-Zeev, 2000). The favourable comparison that evokes this pleasure therefore points to both the mentalizing processing that underlies this emotion and the positive aspects of experiencing it. On the other hand, it has been suggested that the experience of envy is complex and engages particularly negative primary emotions, such as anger, as well as other emotions, such as sadness and fear (Parrott, 1991). In the present study, lesions particularly in the right VM were associated with impaired understanding of envy. In line with this, a recent case study suggests that pathological jealousy (Othello syndrome) may be related to right orbitofrontal damage (Numero *et al.*, 2006). Blair and Cipolotti (2000) have also emphasized the role played by the right VM in responding to negative emotions, such as anger. The authors reported a single case study of a patient suffering from PFC damage including the VM who specifically showed impairment in the recognition of, and autonomic responding to, angry and disgusted expressions. The authors concluded that this impairment was due to a reduced ability to generate expectations of others' negative emotional reactions, anger in particular, and proposed that the right VM may be implicated specifically either in the generation of these expectations or the use of these expectations to suppress inappropriate behaviour. According to this hypothesis, impaired recognition of envy is based on these patients' deficits in anticipating the emotional reactions of other people, particularly negative reactions.

Taken together, Davidsons' 'valence' theory appears to be compatible with our results regarding asymmetry of lesions, as patients with left-sided lesions were doing poorly in the gloating conditions (positive emotion) and patients with right-sided lesions were doing worse in the envy conditions (negative emotion). Nevertheless, the results of the present study regarding lesion asymmetry should be treated with caution since the standard deviations of groups were very high and since the INF group included only patients with left lesions. Additionally, it would be expected that patients with bilateral damage should behave similarly to patients with unilateral damage. As may be seen in Fig. 5, in the gloating condition, indeed the bilateral patients were as impaired as the left-lesioned patients. However, in the envy condition the bilateral group was even better than the patients with right hemisphere lesion. These inconsistencies which may reflect the high standard deviations, somewhat undermines the conclusions regarding lesion asymmetry.

The role of ventromedial prefrontal cortex in social emotions

The ventromedial prefrontal cortex is thought to be important in various complex behaviours. Indeed, neurological research has demonstrated that patients with VM lesions exhibit several impairments such as in inhibition (Rolls *et al*., 1994), in decision-making (Bechara *et al*., 1998; Fellows *et al*., 2007), in empathic processing (Shamay-Tsoory *et al*., 2003) and in the experience of regret (Camille *et al*., 2004). One may wonder what are the common characteristics between these behavioural deficits and the impairments in understanding gloating and envy that were observed in the present study.

A common denominator that these emotions and behaviours have is that all are complex, and involve integration and comparisons between several perspectives. While empathy involves decoupling of observers' and targets' perspectives, 'fortune of others' emotions also involve comparison between observers' and targets' emotion or mental state. The experience of regret, on the other hand, requires comparison between the observers' current outcome and a different potential outcome (Camille *et al*., 2004). Comparisons between options are also necessary when making decisions (Bechara *et al*., 1998). It might, therefore, be assumed that the VM is engaged in situations where two or more possibilities must be processed simultaneously, such as one's own, as well as the other's, emotional mental state. Moreover, perhaps, it is the lack of inhibition of their own perspective that interferes with these patients' ability to process simultaneously their own and the other perspectives.

Indeed, the 'inhibition hypothesis', proposed by Sahakian and colleagues (Plaisted and Sahakian, 1997; Rahman *et al*., 1999) suggests that damage to the prefrontal cortex results in loss of inhibitory control over inappropriate responses to any current situation. Rahman *et al*. (1999) examined patients with frontal variant of frontotemporal dementia, and found that these patients' aberrant social behaviour was related to the inability of their ventromedial inhibitory mechanisms to suppress inappropriate behaviours elicited by the immediate environment. The authors suggest that these patients' behaviour is predominantly controlled by immediate emotional evaluation of the stimuli, and therefore, such disinhibition disrupts the selection of alternative and more appropriate action plans which are dictated by long-term goals.

This view may regard the deficit in recognizing 'fortune of others' emotion observed in patients with VM damage as stemming from a difficulty in inhibiting their own perspective and comparing alternative perspectives of others. Envy and gloating are complex emotions that involve social comparison. While envy is related to comparison between the observers' negative situation and the protagonists' positive situation, gloating is related to comparison between observers' positive situation and the protagonists' negative situation.

Additionally, it appears that both gloating and envy are more related to social comparisons than identification, since they are evoked particularly in competitive situations. Similarly to envy and gloating, identification encompasses a comparison process between the other and self, but to a lesser extent. As such, it requires less mentalization efforts. Recognition of identification might be easier as it involves spotting visual similarities (information processing reason) and since it requires less mentalization efforts. It may be argued that while gloating and envy involve understanding of rivals in competitive situations, understanding of identification may involve understanding of a collaborative protagonist.

Indeed, in an fMRI study, Decety *et al*. (2004) scanned individuals playing a computer game, according to a set of predefined rules, either in cooperation with or in competition against another person. The authors reported that the fronto-parietal network was involved in both cooperation and competition conditions. Yet, in competition, compared to the collaboration condition, activations were observed particularly in the inferior parietal and medial prefrontal cortices. These cortices have been shown to be consistently involved in mentalizing. Therefore, the authors argued that competitive situations recruit the mentalizing network more prominently to evaluate the rival response. The results of Decety and his colleagues are in accordance with the present study and further highlight the involvement of the VM and the inferior parietal lobule in competitive emotions.

While substantive treatment of this issue is well beyond the scope of the current study, it may be interesting to speculate whether competitive emotions encourage emotional mentalizing processing, and thereby engage more ventral PFC cortices. Indeed, the intimate connections of the VMPFC with limbic structures place it in a position to evaluate and regulate incoming limbic information which can consequently be used to perceive social emotions. In agreement with this assumption, two studies have highlighted the role of fronto-limbic circuits in understanding social emotions. While Adolphs *et al.* (2002) report that patients with unilateral or bilateral amygdala damage were impaired when recognizing social emotions, Shaw *et al.* (2005) recently reported that damage to either the left or the right amygdala was associated with impairment in recognition of both social and cognitive expressions. Lesions to the entire right prefrontal cortex led to a specific deficit in recognizing complex social expressions with a negative valence.

There are several limitations that need to be acknowledged and addressed regarding the present study. The first limitation concerns patients' variability in lesions aetiologies. Although most of our sample included patients with traumatic injury, the proportion of these patients is higher in the VM and MIX groups (but not in the INF group). Although patients with MRI evidence of diffuse axonal injury were excluded from the study, one cannot be completely certain that none had diffuse damage that was not observed in MRI. MRI identifies the injury using signs of oedema, which may not be present in all cases of diffuse damage. Patients with MIX damage showed deficits in several cognitive functions as well as in recognizing 'fortune of others' emotions. Additionally, their reaction time in all conditions was slower than the other groups even in the physical conditions. Although their lesion sizes did not differ significantly from the rest of the groups, it appears that they had slightly larger lesions that, perhaps, involved diffuse damage.

Finally, one may argue that the observed impairments in perception of envy and gloat in comparison to identification or basic ToM may simply represent the relatively greater complexity of these conditions. To rule out this possibility, we assessed whether perception of 'fortune of others' emotions related to IQ, years of education or impaired executive functions. It is important to note that the task, relying on visual presentation, involved minimal memory of executive load. In addition, patient difficulties in the 'fortune of others' emotions did not correlate with any measurement of executive function nor with intellectual functioning, suggesting that identifying these emotions was independent of other cognitive functions. Indeed, many authors from a variety of theoretical perspectives have argued that mentalizing involves a domain-specific cognitive module (e.g. Sperber, 2000). The lack of correlation between these emotions and cognitive functioning is consistent with this hypothesis, but any such conclusion must be regarded with caution. Nonetheless, it may be interesting to speculate whether the ability to understand 'fortune of others' emotion may simply represent a higher order affective ToM. Indeed, in the 'fortune of others' conditions in our study, participants had to make second-order affective inferences: how a character feels in regard to a protagonist's emotional state. This suggestion, however, may be refuted by the lack of effect in the identification condition. Future studies may help elucidate this point using tasks designed to assess the experience rather than recognition of these emotions.

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